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Baseline

Plastic ingestion by the northern fulmar (*Fulmarus glacialis*) in Iceland

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ABSTRACT

In 2011, northern fulmars (*Fulmarus glacialis*) from Iceland were used to test the hypothesis that plastic debris decreases at northern latitudes in the Atlantic when moving away from major human centres of coastal and marine activities. Stomach analyses of Icelandic fulmars confirm that plastic pollution levels in the North Atlantic tend to decrease towards higher latitudes. Levels of pollution thus appear to link to regions of intense human coastal and marine activities, suggesting substantial current inputs in those areas.

As plastic production increases by 5% per year and global demand reaches over 265 million tons in 2010 (PlasticsEurope, 2011), plastic pollution in the marine environment is likely to remain an controversial topic (Thompson et al., 2009). Besides having economic costs like clean-ups and losses of valuable material, marine plastic debris is known to have many negative environmental impacts (Thompson et al., 2009). Entanglement and ingestion of plastic by various marine species of all trophic levels have been described (e.g. Laist, 1987; Derraik, 2002). In recent years, a new concern has emerged: the health effects of plastic components and additives on wildlife and humans (Oehlmann et al., 2009). Such concerns emphasize the urgency of establishing monitoring programs for marine plastic litter (Ryan et al., 2009).

In the Netherlands, long term monitoring of plastic ingestion by northern fulmars (*Fulmarus glacialis*) started in the early 1980s and was established as an annual program from the mid-1990s (van Franeker et al., 2011a). The fulmar is a common seabird that is widely distributed around the North Sea and all over the North Atlantic. It forages exclusively at sea, regularly ingests marine debris, generally does not regurgitate solid particles. As a consequence, its stomach contents indicate levels of pollution encountered by the bird over a certain time and space. After 2002, the Dutch research expanded to all other North Sea countries and the Faroe Islands. Monitoring of plastics in fulmars stomachs has become one of the Ecological Quality Objectives (EcoQOs) set by the Oslo-Paris Convention (OSPAR) for the North Sea (OSPAR, 2008; van Franeker et al., 2011a,b) and is a proposed indicator for Good Environmental Status (GES) in the European Marine Strategy Directive (Galgani et al., 2010). Existing data for the North Atlantic suggested a substantial decrease in marine plastic debris with increasing latitude, but suffered from a major gap in data between temperate waters and high-arctic environments.

In 2011, a sample of fulmars from Iceland became available filling that major gap and allowing a test for the hypothesis of a decrease of plastic debris towards higher latitudes in the Atlantic when moving away from major human centres of coastal and marine activities.

The 58 fulmars used for this study were accidental bycatch of a long line fishery off Hornstrandir, Westfjords, Iceland in April, 2011. The fulmars were stored at −20 °C until dissection in the laboratory of the Natural History Museum of Bolungarvík (Westfjords, Iceland). The dissections were conducted following the Dutch protocol (van Franeker, 2004) including morphometric measurements and data on moult, organ health and body condition. Stomach contents including proventriculus and gizzard were sieved over a 1 mm mesh with cold fresh water. Plastic particles were taken from the sample and shipped to the Netherlands for further analysis and sorted into categories under a Zeiss stereo microscope. For each plastic category, the number of particles was counted and the weight was measured on a Sartorius electronic scale to an accuracy of 0.0001 g. Averages for number and mass of plastics are 'population averages' that include birds without plastic. These averages are mainly presented as arithmetic means and standard error (±se). The relatively small sample and non-normal distributed data with outlying values indicates need for log transformation during analyses. We have done so to calculate geometric mean mass of plastics, adding/subtracting 1 mg of mass at transformation and back-calculation to allow for inclusion of the zero values. Transformation becomes increasingly unsuitable with higher proportions of zero values reducing accuracy in calculations for subcategories of plastic. Another approach to avoid bias from outlying values in non-normal distributions has been chosen in the OSPAR EcoQO

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Table 1
Abundance of plastic in stomachs of Icelandic fulmars, Westfjords, April 2011.

	Sample size	Incidence (%)	*n*	±se	*g*	±se	max g	Geometric mass	EcoQO performance (%)
All	58	79	6.0	±0.99	0.13	±0.04	2.0	0.020	28
Adults	49	82	5.3	±0.89	0.13	±0.05	2.0	0.021	27
Non-adults	9	67	9.7	±4.13	0.14	±0.09	0.8	0.018	33

Table 2
Types of plastic particles in stomachs of Icelandic fulmars, Westfjords, April 2011.

	Incidence (%)	*n*	±se	*g*	±se	max g	Geometric mass
ALL PLASTICS	79	6.0	±0.99	0.13	±0.04	2.0	0.020
Industrial plastic	19	0.4	±0.18	0.01	±0.00	0.1	0.001
User plastic	78	5.6	±0.94	0.12	±0.04	2.0	0.018
Sheetlike	17	0.6	±0.24	0.00	±0.00	0.1	0.000
Threadlike	17	0.4	±0.16	0.02	±0.01	0.8	0.001
Foamed	29	1.0	±0.39	0.01	±0.00	0.2	0.001
Fragments	69	3.4	±0.59	0.07	±0.02	1.3	0.011
Other	5	0.2	±0.16	0.03	±0.03	1.6	0.000

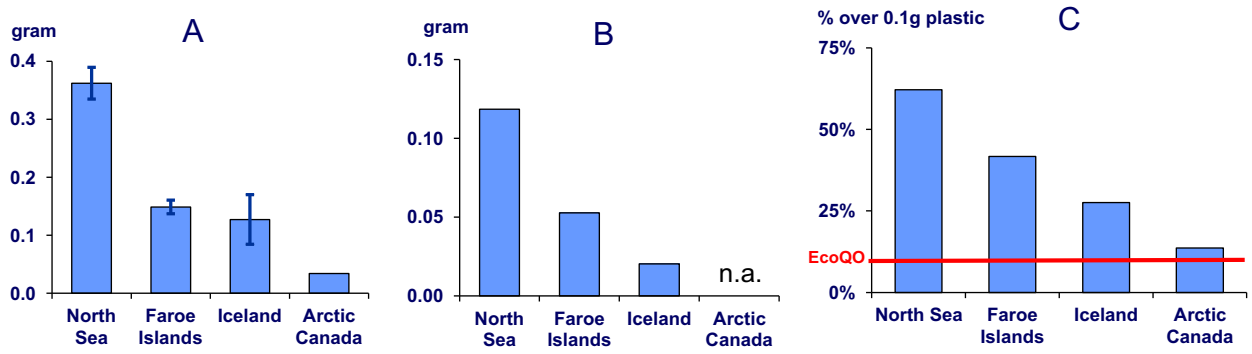

Fig. 1. Patterns in abundance of plastics by mass in fulmar stomachs in the North Atlantic. A = arithmetic mean mass ± standard error; B = geometric mean mass; C = proportion of birds having more than 0.1 g plastic in the stomach (EcoQO performance).

by using the percentage of birds having more than 0.1 g of plastic in the stomach. The EcoQO target for the North Sea is that less than 10% of fulmars exceed the critical 0.1 g level (OSPAR, 2008; van Franeker et al., 2011a). Regional comparisons were made using 2007–2011 data for the North Sea ($n = 682$), Faroe Islands ($n = 333$) and Iceland ($n = 58$) and 2002–2008 data for the Canadian arctic ($n = 169$) derived from data in Mallory et al. (2006), Mallory (2008) and Provencher et al. (2009) with additional information from the authors. Statistical tests of regional differences were conducted in GENSTAT 14th edition, using data from individual birds. For Canadian birds individual plastic weight data were only available for a subsample of 25 birds. Differences in plastic weight were evaluated by fitting a negative binominal generalized linear model with and without region included as a factor and differences between those two models were tested using a likelihood ratio test (Venables and Ripley, 2002; van Franeker et al., 2011a) Regional differences in the incidence and EcoQO performance were evaluated similarly using GLM with Bernoulli distribution.

Of the 58 fulmars, 33 birds were male, 25 birds were females. Age characters indicated 49 adult birds versus 9 non-adults of which one bird was juvenile (1st year), two birds were 2nd year birds and 6 birds were immature (never bred, 3-c.6 years old). All birds were of the double light (LL) colour phase (van Franeker, 2004) and all were in good body condition.

Data on plastic abundance in the stomachs is given in Table 1. Data are also specified for adults and non-adult birds because the long term Dutch study indicates a consistent influence of age on the amount of plastic in the stomach. Details for different categories of plastics are given in Table 2.

The Icelandic birds were all victims from long-line fisheries and were in good physical condition, which differs from the beached corpses in North Sea samples. Beached birds have usually died emaciated after prolonged starvation (van Franeker et al., 2011a). However, analyses in the pilot study for the fulmar project (van Franeker and Meijboom, 2002) showed no statistical difference between plastics in stomachs of emaciated individuals as compared to those that had died instantly in good body condition due to e.g. collisions or drowning. Consequently, data from beached birds from the North Sea can be compared to those from other areas where healthy birds are sampled.

The long term fulmar research has clearly shown that younger birds have more plastics in their stomachs than adults (van Franeker et al., 2011a). This could not be confirmed in the current Icelandic sample (Table 1), but the sample-size for non-adults is only nine birds. Opposite results for arithmetic averages, the number of items and mass and geometric mean mass indicate that the sample size for age groups are too small. Further data are needed.

The overall data confirm decreasing abundance of plastic in fulmar stomachs with increasing latitude in the North Atlantic. Incidence of plastics in Icelandic stomachs is 80%, further south in North Sea and around the Faroe Islands it ranges between 90% and 100% but Canadian Arctic fulmars average at 40% incidence.

Incidence differs significantly between all regions (Faroe–Iceland $p = 0.003$; Faroe–Canada $p < 0.001$ and Iceland–Canada $p < 0.001$), except between the North Sea and Faroe Islands ($p = 0.085$). Stepwise decreases from south to north are shown in Fig. 1. In terms of average arithmetic weight of plastics, the change from Faroese to Icelandic birds (Fig. 1A) is not so clear due to high outliers in the relatively small Icelandic sample (note large standard error). Plastic weight in stomachs of North Sea fulmars differs significantly from all the other regions ($F < 0.001$); differences between the others were not significant, due to smaller sample sizes in combination with high variability. More pronounced differences are indicated by geometric mean mass of plastics. (Fig. 1B) because of the reduced impact of high outliers; such effect is also evident when expressing the data as EcoQO percentage of birds having more than 0.1 g of plastic in their stomachs (Fig. 1C). EcoQO performance differs significantly between all regions (North Sea versus each of the others Chi-square statistics <0.001; Faroe–Iceland $p = 0.038$; Faroe–Canada $p < 0.001$ and Iceland–Canada $p = 0.019$).

Industrial plastics were relatively uncommon in stomachs of Icelandic fulmars (5% of overall plastic mass) compared to industrial plastics in fulmars from the North Sea (20% of overall plastic mass). This fits a pattern where industrial plastics seem more uncommon in fulmars from arctic Canada (Mallory et al., 2006; Mallory, 2008), which suggests that the pelagic distribution of these granules is more strongly linked to industrial point sources than consumer wastes.

This is the first assessment of abundance of plastic debris in stomachs of Icelandic fulmars. Data confirms that plastic pollution levels in the North Atlantic tend to decrease towards higher latitudes. Levels of pollution thus appear to link to regions of intense human coastal and marine activities, suggesting substantial current inputs in those areas.

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