Marine Environmental Research 120 (2016) 122–129

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

The use of beached bird surveys for marine plastic litter monitoring in Ireland

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A R T I C L E I N F O

Article history:
Received 7 June 2016
Received in revised form
28 July 2016
Accepted 1 August 2016
Available online 2 August 2016

Keywords:
Ingestion
Plastic litter
Fulmar
Multispecies
Beached bird survey

A B S T R A C T

Marine plastic litter has become a major threat to wildlife. Marine animals are highly susceptible to entanglement and ingestion of debris at sea. Governments all around the world are being urged to monitor litter sources and inputs, and to mitigate the impacts of marine litter, which is primarily composed of plastics. European policies, such as Oslo-Paris Convention (OSPAR) and Marine Strategy Framework Directive (MSFD) have adopted the monitoring of a seabird species, the Northern Fulmar (*Fulmarus glacialis*), as an environmental quality indicator through the analysis of stomach contents of beached Fulmar specimens. The aims of this research were to: firstly set a baseline investigation of multispecies of seabirds in Ireland affected by the ingestion of litter and, secondly to investigate the feasibility of using Fulmar and/or other potential species of seabird as an indicator for marine debris in Ireland through beached bird surveys. Within 30 months, 121 birds comprising 16 different species were collected and examined for the presence of litter. Of these, 27.3% (n = 33) comprising 12 different species were found to ingest litter, mainly plastics. The average mass of ingested litter was 0.141 g. Among 14 sampled Northern Fulmars, 13 (93%) had ingested plastic litter, all of them over the 0.1 g threshold used in OSPAR and MSFD policy target definitions. Results show that seabirds in Ireland are ingesting marine litter, as in many other countries in the world. Monitoring seabird litter ingestion has the potential to form part of a wider marine litter monitoring programme that can help to inform mitigation and management measures for marine litter.

1. Introduction

Marine litter has become a global concern. It has been estimated that at least 8 million tonnes of plastics enter the oceans every year (Jambeck et al., 2015) and plastics comprise >90% of marine litter (Galgani et al., 2015). Gall and Thompson (2015) list 693 marine species directly affected by marine litter through documented ingestion or entanglement.

The Northern Fulmar (*Fulmarus glacialis*), due to its abundance in the North Atlantic, extensive distribution, oceanic niche and its inclination to ingest marine litter, has been chosen as an indicator species for European policy compliance, such as the Oslo-Paris Convention (OSPAR) and the Marine Strategy and Framework Directive (MSFD). The use of this species to monitor marine litter originated in the Netherlands (Van Franeker and Meijboom, 2002) and, due to its efficacy, it has been incorporated into policy and expanded to other countries, where appropriate (Van Franeker and SNS Fulmar Study Group, 2013; Van Franeker et al., 2011). OSPAR has set a target for an acceptable amount of litter (EcoQO – Ecological Quality Objective) at 0.1 g of plastic in no more than 10% of Fulmars found in samples from between 50 and 100 birds over a period of at least 5 years (OSPAR, 2010). The selection of a certain species as an indicator allows for analysis of trends and data comparison with other parts of the world if methodology is standardized. However, a multispecies approach may facilitate investigation of factors driving certain species to ingest plastic litter or account for variation in composition, amounts and trends among different species. Such an approach may also be useful in determining alternative species for use in a monitoring programme.

A recent study (Lusher et al., 2014) estimated an average number of 2.46 plastic particles m^{-3} in the Northeast Atlantic; however most of particles identified (89%) were classified as microplastics (<5 mm) and 96% of items were thin, dust like fibers. Plastic litter was also reported in the stomachs of True's beaked whales stranded

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http://dx.doi.org/10.1016/j.marenvres.2016.08.002

on Irish beaches (Lusher et al., 2015). Fisheries related litter was reported to be 51% of all litter reported in Irish waters during Bottom Trawl Surveys between 2010 and 2014 (Moriarty et al., 2016). While there is little information on abundance and distribution of marine litter in Ireland there is no published information concerning marine litter and seabirds in Irish waters.

Ireland, along with Great Britain, is home to almost 8 million breeding seabirds, comprising 25 different species, including 90% of the world's Manx Shearwaters (*Puffinus puffinus*), 68% of Northern Gannets (*Morus bassanus*), and 60% of Great Skuas (*Stercorarius skua*). About 34,000 pairs of Northern Fulmars breed in Ireland (Mitchell et al., 2004). Seabirds provide robust environmental monitoring information because they are long-lived, philopatric species and top predators that feed on a variety of levels of the food chain (Furness and Camphuysen, 1997). In order to investigate the feasibility of implementing a marine litter programme that could contribute to reporting for OSPAR and MSFD the work described here intended to: (1) provide a baseline assessment of the prevalence of marine litter affecting multi-species populations of seabirds in Ireland and to discuss the implications of said data; (2) investigate the implementation of the EcoQO for marine litter monitoring in Ireland.

2. Materials and methods

2.1. Sampling

The Republic of Ireland Beached Bird Survey (RIBBS) was a project created in January 2014 to collect dead seabirds along the shore and use them in an attempt to describe the ingestion of marine litter by seabird species in Ireland. Sampling for the current analysis continued to April 2016 and thus covers just over two years of effort. Two Fulmars collected during a preliminary survey in 2012 have been added to the results. Volunteers walked their selected beaches regularly and collected or reported the presence of dead seabirds of any species for subsequent return to the co-ordinator (Fig. 1). Birds were kept frozen (−20 °C) at the Marine & Freshwater Research Centre at the Galway-Mayo Institute of Technology, in Galway, until dissection.

2.2. Dissections

Dissections were performed following the methodology of Van Franeker (2004) to allow for data comparability. Birds were scored for general condition index (0–9) according to the sum of subcutaneous fat, breast muscle and intestinal fat scores. Each organ was also scored for health condition. Age (juvenile, immature and adult) and sex were determined according to plumage and the maturity of sexual organs.

After dissection, stomach contents were washed and sieved through a 1 mm mesh following methods in Van Franeker et al. (2011). All solids were retained and air-dried overnight (Fig. 2). Contents were then examined under a Stereo microscope (MicrosAustria, 0.6x - 5x) and separated into categories according to Van Franeker et al. (2011). Litter items were divided into sub-categories (within plastic and non-plastic litter). As the focus of this study is plastic litter, plastic items only were weighed per sub-category to the nearest 0.0001 g.

2.3. Statistical analysis

Multi-species modelling was performed using R Core Team (2015) (package: lme4 version 1.1–12 (Bates and Mächler, 2016);); through a two-step approach (Duan et al., 1984; Min and Agresti, 2002), in which we assume that the data are generated by two underlying processes. The first process is modelled by a Bernoulli model which determines presence/absence ('prevalence') of litter in birds' stomachs. Conditionally on the positive outcome, the second process is modelled by a Gamma model and determines the amount of litter. This two-step approach is needed because the data are zero inflated (73% of the data is composed of zeroes). For both steps a Generalized Linear Mixed Model (GLMM) was used. GLMM is an extension of Generalized Linear Models (GLM), which includes both fixed and random effects (hence mixed models) in a linear predictor, via maximum likelihood.

On the first step, the data was analysed for presence/absence ('prevalence') of plastic litter in birds' stomachs. A linear predictor for 'Litter Presence' is the combination of the fixed and random effects. 'Family' was included as a random effect allowing for random intercept for each family. This is because birds within families are expected to correlate, whereas birds between families do not. All other variables were included as a fixed effect. This first step was modelled with a logit link function for having zero (no plastics) or positive values (plastics present), and included all variables assumed to influence the presence/absence of plastic litter. The fixed explanatory variables were: 'Sex', 'Age' and 'Feeding Source'. The model specification was: Litter.

Fig. 1. Beached Northern Fulmar (*Fulmarus glacialis*) at Connemara, Co. Galway, 2014 collected during a beached bird survey.

Fig. 2. Stomach contents of beached Northern Fulmar portrayed in Fig. 1. Foam and hard plastic fragments are the main components of sample.

Presence ~ (1|Family) + Sex + Age + Feeding Source. This model included 104 observations as 17 were deleted due to missing values in one or more of the explanatory variables (usually sex or age, as it was not possible to determine these for every individual). Coefficients for 'Age' were very similar to each other as well as their standard errors. This suggests that age group was not of importance to litter presence. To test whether age was useful as a variable, it was then omitted from the model, refit and then compared to the original model according to the change in AIC. The same way, the model was tested by removing 'Family' as a random effect. The model fit was assessed using AIC values.

On the second step, conditionally on the positive outcome of the first step, the amount of plastic litter was modelled using log link function. This step modelled positive values (plastics present), by evaluating plastic litter mass as a function of the same variables as in the first step of the model. Again, 'Family' was taken as a random effect to account for statistical independence of such variable. The model specification was: Litter.Mass ~ (1|Family) + Sex + Age + Feeding Source. Due to aforementioned absence of explanatory data for 9 observations, this analysis was performed with 24 (positive) observations. Additionally, the second step of the model was applied on only the variable ("Family") found to be significant in the previous model to verify for any variation within the family itself and any additional influence by relevant variables. The model specification was: Litter.Mass ~ Species + Sex + Age. Significance level was set at <0.05.

Birds were aggregated into families due to the small sample size for some of the individual species. The variable "Feeding Source" was a factor with 3 levels and it included the species listed in Table 1 with the corresponding sources. The 'Marine' feeding source, included species known to feed mainly offshore; 'Mixed' included species that have a mixed diet that consists of items found in coastal and terrestrial environments (including landfills); and lastly, 'Klepto' included species that are known for kleptoparasitism (Ashmole, 1971).

As birds with no litter (zeroes) represent actual outcomes of the data, they have to be incorporated in the averaged results. Thus averages for number and mass of plastics in stomachs are given as 'population averages', in which all zero values are included with data variability given as standard error (±se) (Van Franeker et al., 2011).

3. Results

For the present study, 121 seabirds were analysed, comprising 16 different species described in Table 2. Specimens were collected in the following years: 2012 (2 – archived samples), 2014 (36), 2015 (62) and 2016 (21) in 12 different counties and four coastal islands (Fig. 3), in Ireland. Of the 121 birds collected, 33 individuals (27.3%) had ingested plastic litter. This represented 12 (75%) of the 16 species collected. The species specific prevalence and abundance by number and mass of ingested plastic litter is listed per species in Table 3.

Plastic ingestion was most prevalent in Northern Fulmars. Among the 14 Fulmar stomachs sampled, there was a 93% prevalence with an average number of 65 ± 33 plastic particles and average mass of 1.1 ± 0.6 g of plastic per individual bird. The 13 Fulmars that contained plastic in their stomachs exceeded the threshold of 0.1 g of plastic as used by OSPAR and EU for defining policy targets of ecological or environmental quality (Fig. 4). The averaged data was strongly affected by a single bird having more than 8 g of plastic in the stomach (Fig. 5). The geometric mean mass of plastics in Fulmars was 0.3367 g. By category of plastic, the average Fulmar had 1.14 industrial particles (0.032 g) and 64 user plastic particles (1.0739 g). Within user plastics sub-category, foam (Av. number = 33, Av. mass = 0.2407 g) and fragments (Av. number = 26, Av. mass = 0.8024 g) were the most frequent items.

Further data for species with sample size exceeding 10 individuals showed contrast between Common Guillemot (12% prevalence) and Razorbill (0%) and plastic ingestion in 27% of Northern Gannets and 32% of Herring Gulls. For species with sample size of 10 or less, see Table 3 for details.

Multispecies samples consisted of 45.4% females (n = 55), 42.1% males (n = 51) and 12.3% of unknown sex (n = 15); 20.7% juveniles (n = 25), 35.5% immature (n = 43), 33.0% adults (n = 40) and 10.7% of unknown age (n = 13). Out of the 33 birds that had ingested plastics, 45.4% (n = 15) were females, 27.3% (n = 9) were males and 27.3% (n = 9) were of unknown sex.

Results from the first step of the multispecies model (GLMM Bernoulli distribution with logit link function) analysis, found the reduced version (excluding 'Age') to be more adequate by comparing AIC values (108.6 × 105.5). Feeding source 'Mixed' is significant in both models, with a stronger significance ($p = 0.0451$) in the reduced model. This suggests that feeding source has an effect on litter presence. Since the responses modelled directly were using a logit link, an inverse of the link function $\exp(x)/(1 + \exp(x))$ was needed to extract and back transform the fixed effect terms and interpret the model. Such approach has shown that the significant value for 'Mixed' feeding source needs to be taken with caution as the predicted probability of litter presence in a bird with a mixed feeding type is 18.46%. When looking at 'Family'

Table 1
Feeding source aggregation as well as family grouping are described by species' scientific and common names. Due to the small sample size for some species, these were grouped into families to make statistical analysis possible. Definitions are provided in 'Material and Methods' section.

Species (common name)	Scientific name	Feeding source	Family grouping
Black Guillemot	*Cepphus grylle*	Marine	Alcidae
Black-legged Kittiwake	*Rissa tridactyla*		Laridae
Common Guillemot	*Uria aalge*		Alcidae
European Shag	*Phalacrocorax aristotelis*		Phalacrocoracidae
Manx Shearwater	*Puffinus puffinus*		Procellariidae
Northern Fulmar	*Fulmarus glacialis*		Procellariidae
Northern Gannet	*Morus bassanus*		Sulidae
Razorbill	*Alca torda*		Alcidae
Sabine's Gull	*Xema sabini*		Laridae
Atlantic Puffin	*Fratercula arctica*		Alcidae
Black-headed Gull	*Larus ridibundus*	Mixed	Laridae
Herring Gull	*Larus argentatus*		Laridae
Iceland Gull	*Larus glaucoides*		Laridae
Parasitic Jaeger	*Stercorarius parasiticus*	Klepto	Stercorariidae
Great Black-backed Gull	*Larus marinus*		Laridae
Lesser Black-backed Gull	*Larus fuscus*		Laridae

Table 2
Sample description (sex and age not always known); ordered by sample size.

Species' common name	Sample size (n)	Sex Male/Female	Age Juvenile/Immature/Adult
Common Guillemot	25	13/12	5/10/9
Northern Gannet	15	4/6	2/0/9
Razorbill	15	7/7	1/8/5
Northern Fulmar	14	3/7	3/2/5
Herring Gull	13	5/6	6/4/2
European Shag	10	6/4	1/7/2
Black-headed Gull	9	3/5	1/4/3
Great Black-Backed Gull	4	2/1	0/2/1
Black-legged Kittiwake	4	0/4	2/1/1
Manx Shearwater	3	2/1	0/1/2
Atlantic Puffin	3	3/0	1/2/0
Lesser Black-backed Gull	2	1/0	0/1/1
Parasitic Jaeger	1	1/0	1/0/0
Black Guillemot	1	1/0	1/0/0
Iceland Gull	1	0/1	0/1/0
Sabine's Gull	1	0/1	1/0/0

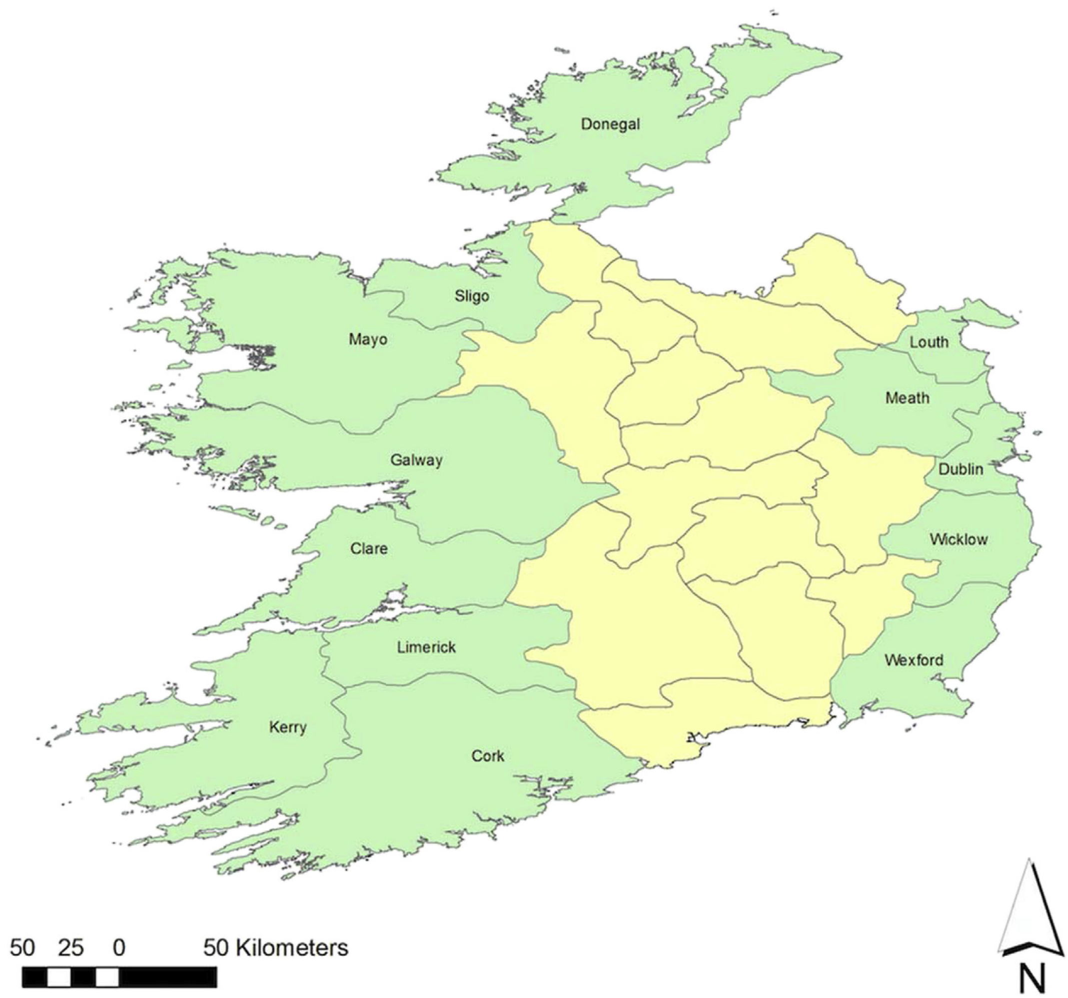

Fig. 3. Counties in green colour denote sampled sites, along with coastal islands off counties Donegal, Dublin and Kerry. Sites on the west are on the Atlantic coast, whilst sites on the east coast are surrounded by the Irish sea. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

as a random effect, the estimated variability in the intercept of the random effect is 1.51, which is distinguishable from zero, meaning therefore that the random effect 'Family' is of importance to the model. The among 'Family' standard deviation is 1.23 and the variance is $1.23^2 = 1.51$. To assess model fit, 'Family' was also removed as a random effect and by comparing AIC values (105.5×115.04), it was confirmed that the GLMM was more adequate than a regular GLM. When interpreting the random effect analysis, the family 'Procellariidae' appears to have a much higher effect on positive litter presence than other families from this study

Table 3
Plastic litter abundance per species (ordered by sample size; population averages are provided and included zero values).

Species	Sample (n)	Prevalence (%)	Average number of particles n ± se	Average mass g ± se
Common Guillemot	**25**	12%	0.12 ± 0.06	0.0001 ± 0.0001
Northern Gannet	**15**	27%	0.46 ± 0.23	0.0225 ± 0.0175
Razorbill	**15**	0%	0	0
Northern Fulmar	**14**	93%	65.35 ± 32.67	1.1147 ± 0.5681
Herring Gull	**13**	32%	1.3 ± 1.22	0.0011 ± 1.1147
European Shag	**10**	10%	0.2 ± 0.2	0.0001 ± 0.0001
Black-headed Gull	**9**	22%	1.33 ± 0.94	0.0063 ± 0.0054
Black-legged Kittiwake	**4**	50%	2 ± 1.41	0.0069 ± 0.0066
Great Black-backed Gull	**4**	25%	9 ± 9	0.0200 ± 0.02
Manx Shearwater	**3**	33%	0.33 ± 0.33	0.0004 ± 0.0004
Atlantic Puffin	**3**	33%	1.33 ± 1.33	0.0077 ± 0.0077
Lesser Black-backed Gull	**2**	100%	1 ± 0	0.4324 ± 0.2786
Parasitic Jaeger	**1**	100%	30	0.0460
Sabine's Gull	**1**	0%	0	0
Black Guillemot	**1**	0%	0	0
Iceland Gull	**1**	0%	0	0

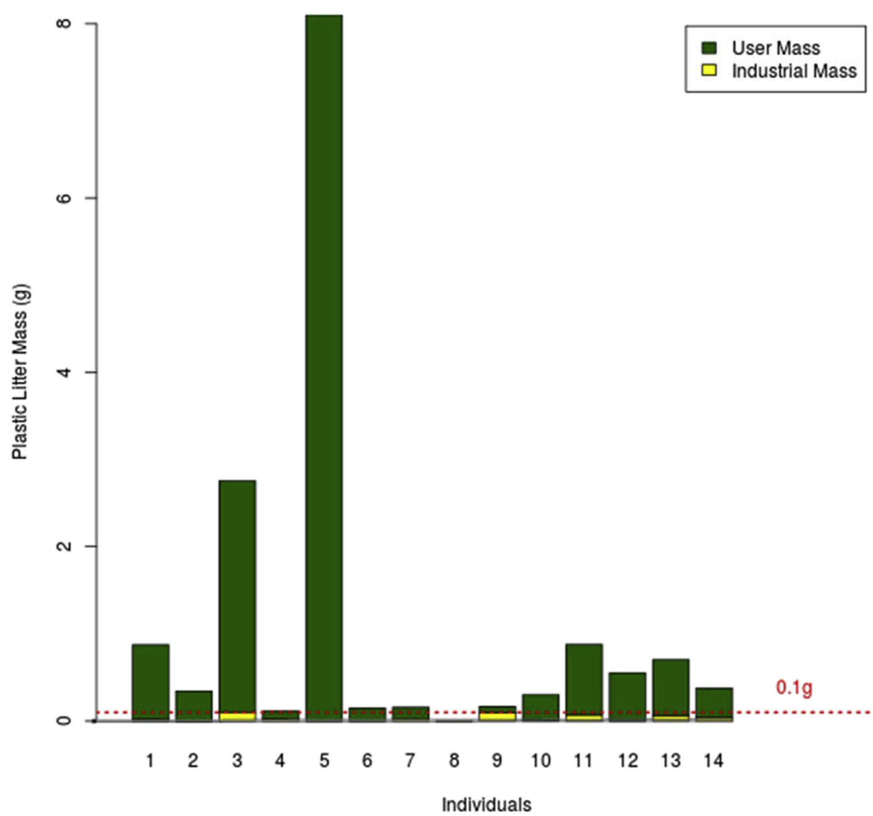

Fig. 4. Individual Fulmars plotted against plastic litter mass. All birds with plastics surpass the EcoQO threshold of 0.1 g. User mass is the main type of plastic litter found, although industrial plastic litter (nurdles) is occasionally present in samples. Individual number 5 is an extreme example, with over 8 g of plastic litter mass. Individual number 8 was the only one that contained no plastics.

(intercept = 0.8692). For a complete list of statistical outputs, see Tables 4A and B.

For the second step of the model, which analysed the positive values for litter presence and investigated the influence of additional explanatory variables such as "Litter Mass", the best fitting model was Gamma with a log link: Litter Mass ~ (1|Family) + Sex + Age + Feeding Source. This model also identified significant effects of the feeding source 'Mixed' ($p = 0.0243$) and 'Marine' ($p = 0.0060$), suggesting that feeding source could have an influence on the amount of plastic litter ingested. Also in accordance with the first step of the model, this part identified significant effects for the family 'Procellariidae'. It was necessary to back-transform random effect using exp(x), which resulted in an intercept = 94.1868, meaning that birds in the family 'Procellariidae' were found to have ingested more plastic litter than the birds from other families analysed. Additional analysis, in which the second part of the model was run using only the Family Procellariidae, which contained only two species (Northern Fulmar and Manx Shearwater), showed a significant difference between these two species regarding the amount of ingested litter ($p < 0.0001$). The variables 'Age' and 'Sex' however did not show significant influence. Caution should be taken when interpreting

Fig. 5. Stomach contents of a beached Northern Fulmar, which amounted to 8 g of plastic litter. Foam and hard fragments are prevalent.

Table 4A
Model output from fixed effects on Step 1. Values are given on a logit scale.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.9540	1.3250	0.720	0.4715
SexM	−0.7298	0.5837	−1.250	0.2112
FeedingMarine	−1.8235	1.2491	−1.460	0.1443
FeedingMixed	−2.4389	1.2174	−2.003	0.0451*

Table 4B
Model output from random effects on Step 1. Values have been back-transformed using exp(x)/(1 + exp(x)).

	(Intercept)
Alcidae	0.2892417
Laridae	0.5028966
Phalacrocoracidae	0.3604330
Procellariidae	0.8692135
Stercorarius	0.6217054
Sulidae	0.3393089

results from this study due to limited sample size. Outputs are listed in Tables 5A and B.

4. Discussion

This study intended to provide baseline data for marine litter in seabirds in Ireland. Our results have shown that at least 12 out of the 16 analysed species have ingested plastic litter. In agreement with other studies globally, Alcids (Guillemots, Razorbills and Puffins) are shown to ingest low levels of plastic litter (9.3%) (Laist, 1997; Provencher et al., 2010; Robards et al., 1995). Procellariiformes, such as e.g. Fulmars and Shearwaters, in accordance with other studies, have high levels of plastic ingestion (82.3%) (Gall and Thompson, 2015; Provencher et al., 2009; Provencher et al., 2014a; Trevail et al., 2015; Van Franeker et al., 2011; Kühn et al., 2015). Based on the current results ($n = 14$ Fulmars) in Ireland there is a 93% prevalence of plastic litter. Since all individual Fulmars with ingested plastic exceeded the threshold of 0.1 g of plastic (Fig. 4), the current EcoQO performance for Ireland is 93%. This, at the moment, exceeds the OSPAR target of below 10%. This value is similar to that seen in the English-French Channel (99%), which is the highest in the North Sea (62%) (Van Franeker and SNS Fulmar Study Group, 2013; Van Franeker et al., 2011; Van Franeker and Law, 2015). Currently, in the Netherlands, 57% of the Fulmars ($n = 171$) exceed the EcoQO between 2010 and 2014 (Van Franeker, 2014). Procellariiformes were statistically significantly (Table 4) more prone to ingesting litter than other families included in this study. Reasons behind the amounts of litter found in Procellariiformes could relate to their surface feeding habits (Mallory, 2006; Van Franeker et al., 2011), which would overlap with positively buoyant plastic debris. Additionally, the narrow connector between the proventriculus and the gizzard, which prevents efficient regurgitation, could perhaps facilitate longer retention times (Ryan, 2015; Van Franeker and Law, 2015). However, when comparing Procellariiformes in this study, there was also a significant difference in the amount of plastic litter ingested by Fulmars and Manx Shearwaters ($p < 0.0001$), though the small sample size of Manx Shearwaters may have contributed to the result. Literature indicates that there are high prevalence and amounts of plastic litter ingested by both species as they share similar gastrointestinal tract morphology (Acampora et al., 2014; Bond et al., 2014; Kühn et al., 2015; Lavers et al., 2014); however Fulmars are reported to be the species with the highest number of individuals ingesting debris (Gall and Thompson, 2015).

For the Suliformes (Gannets and Shags), most studies have reported nest incorporation of debris rather than ingestion (Bond et al., 2012; Montevecchia, 1991), as ingestion seems to be low for this order (Codina-García et al., 2013; Laist, 1997). However a study has reported death by starvation of a Northern Gannet by the occlusion of the digestive tract by debris (Pierce et al., 2004). The reported prevalence in Suliformes from the current study (26.7%) is similar to the 23.9% reported for Pelecaniformes by Kühn et al. (2015), but higher than the 13% reported for Northern Gannets alone in the Mediterranean (Codina-García et al., 2013).

Birds from the family Laridae ingested less litter (26.5%) than expected as some of these species have mixed diets, and are known to feed from terrestrial areas such as landfills (Belant et al., 1998; Duhem et al., 2003; Lindborg et al., 2012), for instance. However, birds that regurgitate their stomach contents, such as most gulls, likely eject indigestible matter at least once a day (Barrett et al., 2007). Thus stomach contents from necropsies might be a reflection of this emptying. The family Laridae are not suitable candidates for oceanic marine litter monitoring, but could be the subject of other types of studies, such as occurrence, type of debris, retention times and, more appropriately, the monitoring of coastal areas.

Table 5A
Model output from fixed effects on Step 2. Values are given on log scale.

	Estimate	Std. Error	t value	Pr(>|z|)
(Intercept)	−0.6871	1.7774	−0.387	0.69906
SexM	−0.5229	0.9628	−0.543	0.58707
Age.L	0.0252	0.5711	0.044	0.96480
Age.Q	−0.3774	0.7880	−0.479	0.63205
FeedingMarine	−3.4094	1.5145	−2.251	0.02437*
FeedingMixed	−3.9973	1.4560	−2.745	0.00604**

Table 5B
Model output from random effects on Step 2. Values have been back-transformed using exp(x).

	(Intercept)
Alcidae	0.4881587
Laridae	0.8400705
Phalacrocoracidae	0.1294125
Procellariidae	94.1868416
Stercorarius	0.2555198
Sulidae	0.5313960

Ingested litter in the stomach of beached birds reflects temporal trends and/or spatial difference of plastic litter abundance at sea (Van Franeker et al., 2011; Van Franeker and Law, 2015), but there is no way of inferring what the amount of ingested litter represents in terms of the quantitative abundance of plastic litter at sea. An individual bird could have been carrying a larger amount of litter and may have passed some of it either through regurgitation, faeces, or through feeding of chicks. For species that regurgitate indigestible matter, perhaps a better way to collect information about these would be through the collection of boluses at breeding colonies (Avery-Gomm et al., 2013; Hammer et al., 2016; Ryan and Fraser, 1988). For birds that cannot regurgitate, it is necessary to assess how much these birds can carry as extra weight without affecting their regular activities. For instance, research that involves satellite or other tracking devices has come to the conclusion that birds can carry approximatelyan additional 3–5% of their body mass (Adams et al., 2009) without having their regular niche activities negatively affected. However, recent studies have shown that even when the 3–5% rule is applied, some tagged birds have taken longer in regular activities, and took more extensive foraging trips or reduced chick provisioning (Adams et al., 2009; Heggøy et al., 2015). The amounts of marine litter ingested by seabirds reported in this study suggest that except for possible incidental cases (e.g. Fulmar with more than 8 g), they did not die directly from plastic ingestion. If seabirds are however, unable to regurgitate or excrete ingested plastic there may be indirect lethal effects. Several authors have suggested indirect impacts such as reduced foraging efficiency, or a reduced feeding rate due to feeling satiated as the stomach is full (Azzarello and Van Vleet, 1987; Ryan, 1988, 1990).

In addition to gathering baseline data, it was possible with the help of volunteers to collect an amount of birds to investigate presence/absence of litter in birds and to run a pilot marine litter monitoring project. Engaging citizens in environmental work has benefits for society by raising awareness (Smith et al., 2014), for the environment by the large collection of data more effectively (Silvertown, 2009) and allows for local research with international impact. It has become common to involve citizens in beach cleaning efforts (Ribic et al., 1997) and species surveys (Camphuysen, 1998; Parrish et al., 2007; Sullivan et al., 2009); these could be extended to becoming a beached bird survey without greater effort.

The second aim of the current study was to investigate the implementation of the EcoQO for marine litter monitoring in Ireland. Results from the current study suggest that implementation of a programme utilising OSPAR's and MSFD's Common Indicator (Vinet & Zhedanov, 2010) for marine litter can be achieved in Ireland. Although numbers of beached Fulmars can be unpredictable, they can provide information and comparability with data collected by other countries in the North East Atlantic. To date, 12 specimens between 2014 and early 2016 (January–April), along with 2 more provided from 2012 before the start of the project, were analysed. This could be considered a small sample. However, according to Van Franeker and Meijboom (2002), a sample of 40 birds is enough to provide one with a reliable figure for plastic ingestion, and in the Irish case such a sample size seems realistically possible for the 5-year time frame used in EcoQO monitoring. Fulmars collected in Ireland had high levels of plastic ingestion, with one Fulmar alone containing over 8 g of plastics.

In order for a species to be considered a good monitor for marine litter, there are some aspects to be considered: 1) monitoring location: offshore or coastal as that will define what species can be considered; 2) local species abundance, through either breeding pairs or migration routes; 3) stranding occurrence; and 4) likely accumulation of ingested marine litter. In addition, certain areas could be difficult to access, thus restricting surveying effort, or the presence of scavengers could reduce carcass availability.

Based on the criteria above and the data gathered in this study, we would not recommend another candidate monitoring species other than Northern Fulmar. An exception could be other Procellariiform species, such as Shearwaters, which have similar internal anatomy permitting the accumulation of debris in the digestive tract. However, some species of Shearwaters appear to feed more at the sub-surface than Fulmars, which are surface feeders (Mallory, 2006). Perhaps this results in Shearwaters encountering litter/plastic less frequently than Fulmars, as most plastics are positively buoyant, at least before they are colonized by organisms (Wright et al., 2013). The higher rate of plastic ingestion by Fulmars compared to Manx Shearwaters seen in this study could also be attributed to regional or species-specific differences, as some species of Shearwaters, such as Great, Sooty and Short-tailed Shearwaters have among the highest rates of ingestion of marine litter (Provencher et al., 2014b).

5. Conclusion

The prevalence of plastic ingestion by seabirds in Ireland is at similar levels to other parts of the world. Additionally, current data indicates the marine litter monitoring through Fulmars in Ireland to be possible. The preliminary data suggest high levels of prevalence of plastic litter ingestion, as well as high litter mass. Although it is important to comply with policy to focus on the Fulmar as a priority monitoring species, this study has shown that different species with different habitats and biology are prone to being affected by marine litter. It is relevant that all occurrences, even at low levels are reported so a better understanding of marine litter is gained globally, which allows for optimal management and mitigation of plastic pollution.

Acknowledgements

This work was supported by Science Without Borders (CAPES, Brazil) and the Department of Housing, Planning, Community and Local Government (DHPCLG, Ireland). We thank all volunteers who have embraced the Republic of Ireland Beached Bird Survey. Without you this project would not be possible. Many thanks to all at BirdWatch Ireland and Clean Coasts. Special thanks to Rosemary Hill, Kieran Campbell, Sean O'Gallaghan, Steve Newton, Niall Keogh, Richard Cronin, Annabel Fitzgerald, Rick Officer, Simon Berrow and Roisin Nash.

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