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# Ingestion of plastic marine debris by Common and Thick-billed Murres in the northwestern Atlantic from 1985 to 2012

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ABSTRACT

Plastic ingestion by seabirds is a growing conservation issue, but there are few time series of plastic ingestion with large sample sizes for which one can assess temporal trends. Common and Thick-billed Murres (*Uria aalge* and *U. lomvia*) are pursuit-diving auks that are legally harvested in Newfoundland and Labrador, Canada. Here, we combined previously unpublished data on plastic ingestion (from the 1980s to the 1990s) with contemporary samples (2011–2012) to evaluate changes in murres' plastic ingestion. Approximately 7% of murres had ingested plastic, with no significant change in the frequency of ingestion among species or periods. The number of pieces of plastic/bird, and mass of plastic/bird were highest in the 1980s, lowest in the late 1990s, and intermediate in contemporary samples. Studying plastic ingestion in harvested seabird populations links harvesters to conservation and health-related issues and is a useful source of large samples for diet and plastic ingestion studies.



## 1. Introduction

Marine debris, including derelict fishing gear, plastic particles, and other anthropogenic objects, is increasing worldwide (Law et al., 2010; Morét-Ferguson et al., 2010; Hammer et al., 2012). This debris is transported by ocean currents to often remote and isolated locations where wildlife can become entangled or ingest it, sometimes leading to their death (Laist, 1997; Derraik, 2002; Good et al., 2010). As a group, marine birds have a well-documented history of debris ingestion or entanglement in all of the world's oceans, with correlative studies making wide-ranging inferences including no measurable effect, reduced body condition, and death (Kenyon and Kridler, 1969; Connors and Smith, 1982; Ryan, 1987a, 1988; Auman et al., 1997; Laist, 1997; Hutton et al., 2008). Birds have been recorded ingesting user plastic, unprocessed plastic resin pellets (nurdles), plastic sheets, rope, twine, and polystyrene (Ryan, 1987b; Laist, 1997). Many species deliberately ingest small items (e.g., gizzard stones) that aid in digestion (McLelland, 1979), and others consume food items that are attached to debris (e.g., fish eggs attached to floating marine debris, Gray et al., 2012), or have indigestible constituents (e.g., fish-eating birds and birds of prey). Nevertheless, there is a high level of concern about physical effects of plastic debris on marine animals (entanglement, damage to the gastrointestinal tract; Carey, 2011; Votier et al., 2011). In addition to physical damage, marine plastic debris is a source of organic and inorganic contaminants (Mato et al., 2001; Teuten et al., 2009; Bond and Lavers, 2011; Yamashita et al., 2011; Holmes et al., 2012; Tanaka et al., 2013). Studies reporting detailed records of plastic ingestion over space and time, however, are rare (Day, 1980; Day et al., 1985; Robards et al., 1995; van Franeker et al., 2011).

In the northwestern Atlantic Ocean, plastic marine debris was first recorded in the 1960s (Rothstein, 1973), and the quantity of debris originating in fisheries operations is related to fishing effort (Bond et al., 2012). Researchers and conservation practitioners need to move towards understanding the effects of marine debris at both the individual and population levels (Lewison et al., 2012), but because such studies almost certainly will rely on natural populations affected by plastic pollution, the first step toward understanding the effects is determining which species and populations are affected.

Common and Thick-billed Murres (*Uria aalge* and *U. lomvia*) are apex marine predators, and approximately 10 million murres winter in the waters off Newfoundland and Labrador (Donaldson et al.,

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1997; Gaston and Hipfner, 2000; Ainley et al., 2002). The two species differ ecologically in foraging behaviour, with the former generally considered more piscivorous and the latter more planktivorous, although zooplankton are common in the winter diet of both species (Bradstreet and Brown, 1985; Moody and Hobson, 2007). From September to March, a legal harvest in the area takes tens of thousands of birds annually (Chardine et al., 1999, 2008; Gaston and Robertson, 2010; Environment Canada, 2011). Recoveries of individuals banded at breeding colonies indicate that murres harvested off of Newfoundland breed not only in Newfoundland and Labrador, but also originate from the Canadian Arctic and from Greenland to Iceland and Svalbard (Elliot, 1987; Bakken and Mehlum, 2005; Gaston and Robertson, 2010). This harvest has resulted in several studies of murres, including their diet, through direct collaboration with harvesters (Gaston et al., 1983; Elliot et al., 1990; Rowe et al., 2000), however, there has been no assessment of ingestion of marine debris outside the breeding season. Previous studies have measured the frequency of plastic ingestion by auks other than murres (Day et al., 1985; Harris and Wanless, 1994, 2011; Robards et al., 1995; Bond et al., 2010). In the Canadian Arctic, 11% of breeding Thick-billed Murres were recorded with ingested marine debris in 2007–2008 (Provencher et al., 2010), much higher than previously recorded in the Canadian Arctic from 1978 to 1979 (1% frequency of occurrence), and the North Pacific between 1969 and 1990 (0.0–1.4% frequency of occurrence) (Day et al., 1985; Robards et al., 1995).

Our objectives were to (1) describe the quantity and type of marine debris ingested by murres harvested in Newfoundland, (2) assess changes in ingestion rates of marine debris by murres between the 1980s, 1990s and the 2010s, and (3) compare temporal changes in debris ingestion by murres to temporal trends in other marine birds globally.

## 2. Methods

Data on plastic ingestion were recorded but not published by Elliot et al. (1990) for birds collected in 1985–1986 (although they were summarized by Heneman, 1988), and were summarized by Rowe et al. (2000) for birds collected in 1996–1997. Briefly, murres were shot along the northeast coast of Newfoundland during October–March (in accordance with Canadian federal murre harvest regulations). Specimens were identified to species (Common or Thick-billed Murre), proventriculus and gizzard were removed from each bird, and plastic was removed, enumerated, and identified. Age (juvenile or > 1 year) of individuals was not systematically recorded during the 1980s but was recorded during the 1990s. In some cases (1980s samples), plastic pieces were weighed to the nearest 0.01 g and measured to the nearest 0.1 mm.

From November 2011 to February 2012, we collected 33 murres from Twillingate (49.67°N, 54.79°W), six from St. Mary's Bay (46.93°N, 53.69°W), and four from Conception Bay, Newfoundland (47.75°N, 53.00°W) under permit from Environment Canada. Specimens were identified to species (Common or Thick-billed Murre) and were aged (juvenile or >1 year), gastrointestinal tracts were removed, and all plastic was enumerated following methods described by Provencher et al. (2010) and van Franeker et al. (2011). Each piece was weighed to the nearest 0.00001 g with a Scaltec SCB22 analytical balance, and categorized as rigid plastic, soft plastic, fibres, or other plastic. Rigid and soft plastic debris were measured to the nearest 0.1 mm using callipers along all three axes (length, width, height).

### 2.1. Statistical methods

Changes in the frequency of occurrence of plastic over time, and differences in ingestion rates between species were tested with a generalized linear model (GzLM) with a binomial error structure, and changes in the number of pieces of plastic/bird was tested with a Poisson GzLM. We used an analysis of variance (ANOVA) to examine differences in plastic mass per bird between the 1980s and 2010s (data for 1990s were not available). Analyses were done in SPSS 21 (IBM Inc., Redmond, Washington, USA). Values are presented as population means ± SD (i.e., including birds without plastic).

## 3. Results

Our total sample consisted of 1592 Thick-billed Murres and 71 Common Murres from all time periods. In 1985–1986, 96/1249 murres (7.7%) had plastic marine debris in either their gizzard ($n = 92$) or stomach ($n = 4$). All murres examined were Thick-billed Murres; data on their ages were not available. The colour was recorded for about one third of those birds with debris ($n = 33$ birds, $n = 107$ pieces of plastic), and was predominantly yellow (100/107). We also recorded green (2/107), transparent (2/107), orange (1/107), red (1/107), and white plastic (1/107). Individual birds contained between 0 and 8 pieces of debris, and each bird contained an average of 0.14 ± 0.70 pieces. The mass of debris ranged from 0.00 to 0.67 g/bird (mean: 0.005 ± 0.041 g), the length ranged from 3.5 to 39.0 mm (mean: 10.1 ± 7.4 mm), and the width ranged from 1.0 to 11.0 mm (mean: 4.6 ± 2.5 mm). Many pieces of debris were small yellow balls of unknown origin, but we also recorded rope (including twine, fishing line, fibrous material), pieces of bags, and bottle caps; all material recorded was user plastic, and no unprocessed pellets were found (see Table 1).

In 1996–1997, 16/370 murres (4.3%) contained plastic. Of these, one was a Common Murre, and 15 were Thick-billed Murres (9 first-winter birds, and 6 adults). Every bird that had ingested debris contained either one ($n = 14$, including the single Common Murre) or two ($n = 2$) pieces of debris. Seven birds contained hard user plastic, two contained a piece of plastic bag, and eight had rope-like material. We also recorded one bird with electrical wire sheathing. No birds contained industrial pellets.

In 2011–2012, 4/43 murres (9.3%) contained marine debris. All four were first-winter birds (one Common and three Thick-billed Murres). Every bird contained a single piece of user plastic that weighed an average 0.0203 ± 0.0162 g (range: 0.0066–0.0438 g). The four pieces averaged 6.6 ± 2.2 mm wide (range: 4.6–9.5 mm), 4.0 ± 1.6 mm long (range: 2.8–6.4 mm), and 1.3 ± 0.8 mm thick (range: 0.5–2.4 mm). Murres contained 0.091 ± 0.291 pieces (0.0018 ± 0.0073 g) of plastic on average. Three of the plastic pieces were white hard plastic, and the fourth was black rigid foam; again, no industrial pellets were found.

There were no significant differences in the frequency of plastic ingestion among periods (Wald $\chi^2 = 3.14$, $p = 0.21$) or species (Wald $\chi^2 = 0.47$, $p = 0.49$), or the period × species interaction (Wald $\chi^2 = 0.47$, $p = 0.49$). The number of pieces of plastic in each murre differed significantly among periods (Wald $\chi^2 = 24.64$, $p < 0.001$), with a greater number of pieces in the 1980s than the

**Table 1**
There were no differences in the rate of plastic ingestion among species or periods for murres collected off Newfoundland from 1985 to 2012. COMU = Common Murre, TBMU = Thick-billed Murre. Values are modelled parameters.

| Period | Species | *n* | Mean ± SE | 95% CI | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| 1985–1986 | TBMU | 1249 | 0.08 ± 0.01 | 0.06 | 0.09 |
| 1996–1997 | COMU | 60 | 0.02 ± 0.02 | 0.00 | 0.11 |
| | TBMU | 310 | 0.05 ± 0.01 | 0.03 | 0.08 |
| 2011–2012 | COMU | 11 | 0.09 ± 0.09 | 0.01 | 0.44 |
| | TBMU | 32 | 0.09 ± 0.05 | 0.03 | 0.25 |

1990s ($p < 0.001$); all other pairwise comparisons using estimated marginal means were not significant, and no significant difference was found in the mass of plastic/murre between 1985–1986 and 2011–2012 ($F_{1,1276} = 0.74$, $p = 0.39$).

## 4. Discussion

Deep-water pursuit-diving murres collected in the winter off Newfoundland have been ingesting plastic chronically and at low levels since at least the mid 1980s. Murres harvested off Newfoundland had similar frequencies of plastic ingestion as Thick-billed Murres in the Canadian Arctic did in 2007–2008 (11%; Provencher et al., 2010). Newfoundland murres from the 1980s and 2010s generally had a higher mass of plastic/bird (0.005 ± 0.041 g and 0.0018 ± 0.0073 g respectively) than do contemporary samples from the Canadian Arctic (range of means from five colonies = 0.0003–0.0026 g; Provencher et al., 2010). The frequency of plastic ingestion by murres in the Atlantic Ocean was also much higher than that observed in the North Pacific during 1969–1990 (about 0.0–1.4%, Robards et al., 1995), and the Canadian Arctic in 1978–1979 (Day et al., 1985).

We found no significant difference between Common and Thick-billed Murres in rates of ingestion. In the Pacific Ocean, Thick-billed Murres ingest plastic at a higher rate than do Common Murres (Robards et al., 1995) possibly because Thick-billed Murres' differentially target small zooplankton (Bradstreet and Brown, 1985) that may resemble plastic fragments. The two species have similar winter diets in Newfoundland, (Elliot et al., 1990; Moody and Hobson, 2007).

It is also of note that the murres examined in all three time periods showed ingestion of user plastics, but lacked any industrial raw pellets. This absence could be either because the wintering areas where murres are ingesting the plastics lack industrial pellet debris, or because murres are less likely than other species to ingest industrial pellets in the marine environment. With the data at hand, it is difficult to determine the cause, but future studies that assess ingestion rates in the context of environmental levels of debris should seek to resolve such differences.

There are few long-term datasets on debris ingestion by marine predators (Day, 1980; Harris and Wanless, 1994; Robards et al., 1995; Vlietstra and Parga, 2002; van Franeker et al., 2011). Plastic ingestion by Thick-billed Murres in the Canadian Arctic increased from 1% in 1978–1979 to 11% in 2007–2008 (Day et al., 1985; Provencher et al., 2010). In Alaska, Robards et al. (1995) found a general increase in the proportion of birds that had ingested plastic, but the change for both species of murres was <2%, and of deep pursuit divers in general was <10%. Atlantic Puffins (*Fratercula arctica*) from Scotland also had a low frequency of occurrence, and a steady frequency of plastic ingestion from 1969 to 2007 (Harris and Wanless, 1994, 2011). We also found no significant change in the proportion of birds that had ingested plastic over the 27 years of our study, suggesting that deep-water pursuit-divers have ingested plastic at a relatively constant rate despite increases in oceanic plastic pollution since the mid-1980s (Morét-Ferguson et al., 2010; Hammer et al., 2012). We caution, however, that this apparently low constant rate of plastic ingestion by murres may not continue. Although fishing intensity varies in types of gear used and localities fished, levels of other marine plastic pollution are expected to increase (Thompson et al., 2004; Moore, 2008).

The available data indicate that Procellariiformes, which mostly have shallow foraging dives, generally have higher incidences of plastic ingestion than do the relatively deeper-diving auks, even when foraging in the same area (Robards et al., 1995; Laist, 1997; Provencher et al., 2009, 2010). Our results and those of other studies demonstrate that even murres, which can forage up to 200 m below the ocean's surface, ingest anthropogenic marine debris (Piatt and Nettleship, 1985; Robards et al., 1995; Blight and Burger, 1997; Takahashi et al., 2008; Provencher et al., 2010; Regular et al., 2011). Few other deep-diving seabirds have been recorded ingesting plastic (Day et al., 1985; Ryan, 1987b; Robards et al., 1995; Laist, 1997; Brandão et al., 2011), and although ingested plastic has been recorded in more than 25% of pursuit-diving seabirds, the incidence within these species is generally very low (3%; Ryan, 1987b). Planktivorous species are also more likely to ingest plastic than are piscivores, such as murres (Day, 1980; Day et al., 1985; Azzarello and Van Vleet, 1987; Ryan, 1987b).

The harvest of murres in coastal Newfoundland waters is a consumptive hunt that is widespread across the province, and provides an opportunity to address research questions that require large sample sizes over time (Montevecchi et al., 2007). Plastics transport contaminants and deposit them in bird tissues (Mato et al., 2001; Teuten et al., 2009; Holmes et al., 2012; Tanaka et al., 2013), although the contribution of contaminants associated with plastic debris is probably small relative to trophic sources of pollutants. We require a better understanding of the effects of plastic debris on individuals and populations of marine animals (but see Votier et al., 2011), Monitoring changes in seabird plastic ingestion over time can provide a simple and inexpensive way to quantify poorly understood anthropogenic factors relating to harvested seabirds and also plastic pollution in the marine environment (Mallory et al., 2010; van Franeker et al., 2011). There are few remaining regulated harvests of seabirds worldwide (Richardson, 1984; Skira et al., 1985; Olsen and Nørrevang, 2005; Gaston and Robertson, 2010), but collaboration with harvesters can result in a large sample of otherwise-healthy birds, and can engage local communities in the global issue of plastic pollution.

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