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Plastics and other anthropogenic debris in freshwater birds from Canada

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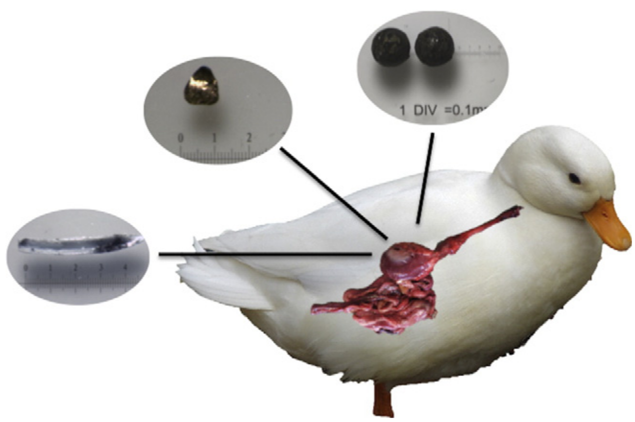
HIGHLIGHTS

- Dissection-based dietary analyses determined freshwater bird debris loads.
- Anthropogenic debris was found in 10 of 18 species.
- Approximately 11% of individuals had anthropogenic debris.

GRAPHICAL ABSTRACT



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ABSTRACT

Plastics in marine environments are a global environmental issue. Plastic ingestion is associated with a variety of deleterious health effects in marine wildlife, and is a focus of much international research and monitoring. However, little research has focused on ramifications of plastic debris for freshwater organisms, despite marine and freshwater environments often having comparable plastic concentrations. We quantified plastic and other anthropogenic debris in 350 individuals of 17 freshwater and one marine bird species collected across Canada. We determined freshwater birds' anthropogenic debris ingestion rates to be 11.1% across all species studied. This work establishes that plastics and other anthropogenic debris are a genuine concern for management of the health of freshwater ecosystems, and provides a baseline for the prevalence of plastic and other anthropogenic debris ingestion in freshwater birds in Canada, with relevance for many other locations.

1. Introduction

Humans have been releasing plastic debris into the environment since the early 1900s (Bijker, 1987). Originally thought to be little more than an eyesore, we now know that the very properties that make plastics ideal for human use (i.e., being lightweight and strong, and having a durable physical configuration) also make plastics serious

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environmental hazards (Laist, 1987; Derraik, 2002). The ubiquity of anthropogenic debris in the environment, such as plastic and waste metal, raises concerns regarding its ingestion by animals, and so has been particularly well-studied for animals living in aquatic habitats (Rochman et al., 2014). Anthropogenic debris is problematic due to its negative effects on wildlife, including entanglement and ingestion (Derraik, 2002; Wright et al., 2013; Provencher et al., 2014). Plastic debris also has an affinity for certain non-essential trace elements and persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT; Ashton et al., 2010; Bakir et al., 2014). Once plastics are discharged into aquatic environments, they can persist for up to 50 years, and their complete mineralization may take hundreds or thousands of years (Gregory, 1978; Derraik, 2002; Driedger et al., 2015). Entanglement and ingestion of marine anthropogenic debris negatively affects all seven known species of sea turtle (100%), about half of all species of marine mammals (45%), and one-fifth of all species of seabirds (21%); these numbers represent a 40% increase (from 247 to 663 affected species) from 1997 (Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel—GEF, 2012). As of 2015, 56% of seabird species were affected by marine anthropogenic debris (Gall and Thompson, 2015), with predictions that by 2050, 99% of all seabird species will be affected (Wilcox et al., 2015) and the mass of plastics in the oceans will outweigh fish (Neufeld et al., 2016). Whereas much is known about effects of plastic debris on marine birds, virtually no comparable data are available for freshwater species.

Freshwater bodies can have comparable plastic concentrations to marine waters (Castañeda et al., 2014; Lechner et al., 2014; Driedger et al., 2015). In the Great Lakes of North America, over 80% of anthropogenic shoreline debris is composed of plastics (Castañeda et al., 2014; Driedger et al., 2015) and sediments of the St. Lawrence River have microbead (polyethylene and polypropylene microspheres widely used in cosmetics as exfoliating agents; Eriksen et al., 2013) pollution comparable in magnitude to marine microplastic concentrations [Castañeda et al. (2014); microplastics defined by Moore (2008) and Arthur et al. (2009) as plastic fragments <5 mm]. Likewise, a multiyear study on the Danube River in Austria quantified discharges of 1533 t of plastics per year into the Black Sea (Lechner et al., 2014), although the majority turned out to be industrial microplastics from a plastic-producing company (Lechner and Ramler, 2015). A similar study in Mongolia found that Lake Hovsgol has plastic particle concentrations reaching 20,264 particles/km^2 (Free et al., 2014), and a recent study on two lakes in central Italy (Lake Bolsena and Lake Chiusi) found 2.68 to 3.36 particles/m^3 and 0.82 to 4.42 particles/m^3, respectively, in surface waters (Fischer et al., 2016). These studies suggest that not only are plastics a major problem in marine settings, they are also an issue in freshwater ecosystems.

Studies focusing on organisms in freshwater ecosystems have found dietary plastic debris in green algae (*Scenedesmus obliquus*) and zooplankton (*Daphnia magna*) (Besseling et al., 2014), as well as planktivorous fish (Sanchez et al., 2014; Moseman, 2015). Plastics could also potentially affect benthivorous fishes and macroinvertebrates [preliminary results on benthic round goby's (*Neogobius melanostomus*) digestive tracts suggest the presence of microbeads (Castañeda et al., 2014) while reports on benthic gudgeon (*Gobio gobio*) found ingested polymer fibers and pellets (Sanchez et al., 2014)]. Migratory birds, such as red phalaropes (*Phalaropus fulicarius*) and red-necked phalaropes (*P. lobatus*), which eat freshwater zooplankton, also consume plastic debris (Day et al., 1985; Moser and Lee, 1992). English et al. (2015) examined mallard (*Anas platyrhynchos*), American black duck (*A. rubripes*), and common eider (*Somateria mollissima*) wintering in Atlantic Canada, and found an 11.5% prevalence of plastics in 140 birds. However, it was not known whether those birds acquired plastic debris in freshwater or marine locations due to the long residency time of dietary plastics (from two months to a year; Connors and Smith, 1982; Ryan and Jackson, 1987) and known movement patterns of these ducks between marine and freshwater ecosystems in this area (English, 2016).

Encounters between organisms and marine debris have been reported since the 1960s, with the first study on seabird plastic ingestion on Laysan albatross (*Phoebastria immutabilis*) conducted in 1966 (Kenyon and Kridler, 1969; Gall and Thompson, 2015). Between 1969–1977 and 1988–1990, a significant increase (up to 26.3%) was recorded in the frequency of seabird plastic ingestion (Robards et al., 1995). If trends in freshwater waterfowl ingestion of debris mirror seabird historical trends, we may see a similar increase in waterfowl debris consumption over time. This is problematic due to negative consequences of consuming debris. Debris fails to provide nutrition proportional to its mass or volume, and can lead to weakness, false feelings of satiation, irritation of the stomach lining, digestive tract blockage, internal bleeding, abrasion, ulcers, failure to put on fat stores necessary for migration and reproduction, absorption of toxins, and potential death through starvation (Moore, 2008; Wright et al., 2013; Zhao et al., 2016).

Surface-feeding birds and dabbling ducks may be particularly susceptible to plastic ingestion due to the initial buoyancy of plastic. Plastics eventually settle over time from biofilm fouling and hitchhiking organisms (Barnes et al., 2009; Driedger et al., 2015; Frias et al., 2010). However, after settling, they remain available to benthic organisms, and those that feed on benthos, and thus can return to food webs (Wright et al., 2013). Due to biomagnification through debris consumed by fish, piscivorous birds may also be at risk (Day et al., 1985; Castañeda et al., 2014; Sanchez et al., 2014; Moseman, 2015). Additionally, urban birds are at an increased risk of ingesting debris because of a greater density of plastic near industrial centers (Zbyszewski et al., 2014).

We undertook this study to bridge a knowledge gap on anthropogenic debris ingestion by freshwater birds. We asked the following questions: 1) What is the prevalence of anthropogenic debris in freshwater birds? 2) Is there geographic variation in prevalence? 3) Are there differences among species in prevalence and does this relate to their foraging niches? 4) Is prevalence related to body mass? 5) What are the characteristics of ingested particles (i.e., type, color and size)?

2. Material and methods

2.1. Sampling

Ducks, geese, and loons occupying freshwater habitats were collected from across Canada (Fig. 1); 40 common eiders (a marine sea duck) were also acquired as a comparison group. All birds were from hunter kills, airport culls or collisions, and predation, and were shipped frozen to Acadia University where dissections were performed. We recorded species, date, location, and if available, sex, age, and body mass (g). Birds were kept frozen at −22 °C until dissection and analysis, and allowed to thaw for one to two days prior to dissection.

2.2. Processing, separation, sorting and identifying

Methods followed the recommendations of van Franeker and Meijboom (2002) and van Franeker (2004) for quantifying anthropogenic debris ingestion by seabirds. To avoid contamination, work surfaces were thoroughly cleaned with a 1/3 to 2/3 bleach and water mixture and all tools were cleaned under running tap water between each specimen. Gloves, lab coats, and facemasks were worn throughout the study. For each specimen, data from the proventriculus and gizzard were evaluated separately to determine debris residency time, because debris particles located in the proventriculus were likely consumed more recently (van Franeker and Meijboom, 2002). Thawed digestive tracts were opened over their full length, and contents carefully flushed with cold tap water above a 0.5-mm mesh sieve to ensure that no small particles were left behind on organ walls (particles smaller than 0.5 mm were detected due to debris' ability to adhere to larger dietary particles). All material was rinsed under running tap water (van Franeker and