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**Chemical identification of microplastics ingested by Red Phalaropes
(*Phalaropus fulicarius*) using Fourier Transform Infrared spectroscopy**

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ABSTRACT

Chemical characterization of plastics ingested by wildlife helps identify sources of plastic pollution in nature and informs assessments of exposure risk to contaminants. In 2016, Red Phalaropes (*Phalaropus fulicarius*) were found dead on the north coast of British Columbia, Canada, during their southward migration. Previously, ingested particles suspected to be plastics were reported upon gut examination in all carcasses collected (n=6), which likely contributed to mortality. Here, we provide chemical identification of the ingested particles using Fourier Transform Infrared (FTIR) spectroscopy. Polymer identification was successful for 41 of the 52 analyzed particles (79%): 41 (79%) were confirmed as plastics, 6 (11%) were not plastics, and 5 (10%) could not be identified. The most commonly ingested plastics were polyethylene (42%) and polypropylene (23%), both of which are known to float in the marine environment. Our study highlights the vulnerability of surface foraging seabirds to plastic pollution in the marine environment.

KEYWORDS:

Microplastics, FTIR spectroscopy, Polymer identification, Seabirds, Red Phalarope, *Phalaropus fulicarius*

INTRODUCTION

Birds that forage in the marine environment are particularly susceptible to ingesting plastic debris. Indeed, these birds may be exposed to floating or sinking debris through their feeding strategies: surface feeding, plunging, and pursuit diving (Ashmole, 1971; Avery-Gomm, Provencher, Morgan, & Bertram, 2013). The low density of some plastic polymers, such as polypropylene (PP, density 0.92 g/cm³), polyethylene (PE, density 0.95 g/cm³) or even polystyrene (PS, density 1.1 g/cm³) (GESAMP, 2015), causes surface feeders to be predominantly exposed to these types of floating plastics (Moser & Lee, 1992). In addition, plastic distribution is not homogeneous at the surface of the ocean, as it is constantly being either dispersed or concentrated by oceanographic currents (Auta, Emenike, & Fauziah, 2017). This leads to greater concentrations of plastic particles closer to the coast, as well as in upwelling areas offshore (Auta et al., 2017; Desforges, Galbraith, Dangerfield, & Ross, 2014; Williams, Ashe, & O'Hara, 2011). Plastics can be considered as both macro and micro contaminants due to their ability to cause physical and chemical harm (Avery-Gomm, Borrelle, & Provencher, 2018). While the physical damage plastics cause as macro contaminants poses threats such as entanglement and starvation (Acampora, Newton, & O'Connor, 2017), the ingested plastics might also be vectors of contaminants, causing less obvious biochemical damage (Silva et al., 2018; Tanaka et al., 2015, 2013).

One marine bird that is particularly vulnerable to plastics is the Red Phalarope (*Phalaropus fulicarius*). This species breeds across the Arctic regions of North America and Europe and has a trans-oceanic migration each year that lasts 11 months (Tracy, Schamel, & Dale, 2002). Red Phalaropes are surface feeders whose diet typically consists of zooplankton found offshore in upwelling areas, and of adult and larval insects on their breeding grounds (Tracy et al., 2002). Red Phalaropes have a high risk of exposure to microplastics through their feeding behaviour, and seem to mistake floating plastic pieces for prey (Avery-Gomm et al., 2016; Moser & Lee, 1992; Provencher, Bond, & Mallory, 2015; Ryan, 1987). This risk may have been exacerbated when coming closer to shore in search for food (Drever et al., 2018). Thus, it is crucial to not only evaluate the threat posed by plastic pollution to this species, but the potential route of exposure to chemical contaminants associated with plastics.

In this study, we determined the polymer composition of plastics ingested by Red Phalaropes during their southward migration. Nine Red Phalaropes were collected on the north coast of British

Columbia, Canada, following a mortality event in the fall of 2016. Micro -and macro- plastic debris were discovered upon gut examination in all carcasses, and the veterinary report indicated that the large amount of ingested plastics contributed to mortality (Drever et al., 2018). Previously, Drever et al., (2018) reported the necropsy results and evaluated plastic ingestion through visual characterization of the stomach contents. Here, we build on this previous work by chemically characterizing the suspected plastics isolated from Red Phalaropes' stomachs using Fourier Transform Infrared (FTIR) spectroscopy in Attenuated Total Reflectance (ATR) mode. The objectives of our study were: (i) to validate whether visual characterization of stomach contents can accurately identify ingested particles as plastics; and (ii) to determine the polymer composition of plastics ingested by Red Phalaropes as part of expanding our knowledge of plastic pollution in the North Pacific. Elucidating which types of polymers are being ingested may help trace sources of marine pollution and lends insights into what contaminants Red Phalaropes are potentially exposed to via ingestion of plastics. Given that Red Phalaropes are surface feeders, we predicted that the plastic pieces would be dominated by polymers that are commonly found in surface waters (e.g. PP, PE and PS).

MATERIALS AND METHODS

Sample collection & processing

The Red Phalaropes examined in this study were collected following a mortality event off the west coast of British Columbia, Canada. In the wake of the tug Nathan E. Stewart sinkage on October 13, 2016, an emergency oil spill response was put in place, including wildlife monitoring for one month. The dead birds that were collected were not oiled, but all were severely underweight (47-64% of their expected weight). Carcasses were frozen upon collection and defrosted 3 to 4 weeks later, prior to necropsy. As per outlined for examining plastic pollution in seabirds in Provencher et al. (2019) stomachs were dissected and particles were sieved to greater than 1 mm under a stream of deionized water, to be visually sorted under a binocular microscope into industrial pellets or used debris (Drever et al., 2018). Individual pieces were then measured, and sorted into eight colour categories using a Munsell colour wheel reported in (Drever et al., 2018), and using the recommended protocol in Provencher et al. (2017). Size distributions of particles are reported by Drever et al. (2018) and it was

determined that less than 1% of particles were less than 1 mm in size. Ingested particles visually suspected to be plastics by Drever et al. (2018) from 6 Red Phalaropes were sent to Queen's University, Canada for chemical characterization for the current study.

Chemical identification of plastic polymers

Chemical identification was performed using FTIR analysis, as it allows for easy identification of carbon-based polymers (Shim, Hong, & Eo, 2017). Each plastic polymer possesses a unique infrared spectrum that acts as a fingerprint (Hidalgo-Ruz, Gutow, Thompson, & Thiel, 2012). This method provides confirmation of the type of polymer in a sample (Song et al., 2015) once the particle is dried and cleaned (Löder & Gerdt, 2015).

A Perkin Elmer micro-FTIR Spectrometer Spotlight 150ir was used to collect spectra from 4000 cm^{-1} to 600 cm^{-1} with a data interval of 1 cm^{-1} . Resolution was set at 8 cm^{-1} , and 32 scans were recorded for each analysis. The ATR germanium crystal was cleaned with ethanol and a background scan was performed between each sample. A subset of samples was also analysed using a Bruker Alpha II FTIR, equipped with a diamond ATR crystal. Spectra were collected from 4000 cm^{-1} to 450 cm^{-1} with a data interval of 1 cm^{-1} . Resolution was set at 4 cm^{-1} , 8 scans were recorded, and a background scan was performed between each sample. Identification was done using a polymer library provided by Perkin Elmer, as well as an open source Bruker database provided by Primpke, Wirth, Lorenz & Gerdt (2018). The integrated software matching algorithms were used to assess the accuracy of the matches, providing either a correlation factor (Perkin Elmer), or a Hit Quality Index (HQI, Bruker). The majority of identified plastics presented a correlation factor higher than 80% and/or an HQI higher than 700. In addition, the protocol described by Jung et al. (2018) was used to differentiate two types of polyethylene (PE) polymers. When a decision between high-density polyethylene (HDPE) and low-density polyethylene (LDPE) could not be made based on visual examination of the spectra, the particle was reported as only PE (Jung et al., 2018).

RESULTS AND DISCUSSION

All of the Red Phalaropes examined in this study (n=6) contained particles in their stomachs visually suspected to be plastic (3 to 24 pieces per bird). As reported by Drever et al. (2018), Red

Phalarope stomachs contained a diversity of particles, including fragments, pellets, sheets, and foams (Table 1, Figure 1e-f). Most were smaller than 5 mm, with the exception of two (a knot of intertwined fibers (5.45 mm) and a plastic sheet (6.24 mm)). All 52 particles isolated from these birds were analysed using FTIR spectroscopy (Table 1).

Overall, 79% of particles in Red Phalarope stomachs suspected to be plastics (based on visual characterization) were confidently classified as plastics when analyzed by FTIR (Figure 2). We identified the particles to be plastics based upon algorithm matching in addition to manual comparison of the acquired spectra to various libraries available. Representative spectra of the most commonly found polymers can be seen on Figure 1 (a-d). However, determination of the specific polymer composition was not always achievable. For instance, searching through the Perkin Elmer polymer database resulted in very similar correlations between several sample spectra and both PE and polyamide (PA) reference spectra. In addition, the use of several libraries led to different results for some plastics. In cases where we were not able to reach a decision, both potential results are reported (Table 1). As per Drever et al. (2018), 92% of the microplastics were characterized as user plastic upon visual observation, as opposed to industrial virgin pellets (Provencher et al., 2017). Thus, these plastics are likely to contain a multitude of additives introduced throughout their industrial transformation, and to have been manufactured from several polymers (Marturano, Cerruti, & Ambrogi, 2017). The industrial alterations the ingested plastics possibly underwent could result in different FTIR spectra than virgin industrial polymer pellets often used in polymer libraries, which complicates identification.

Surprisingly, among the four samples that were easily visually identified as industrial pellets, two identical looking spheres did not lead to any conclusive polymer identification following FTIR analysis. Given their distinctive shape as industrial pellets of plastic, this suggests that polymer libraries may not be comprehensive. Alternatively, environmental exposure may have altered these polymers beyond recognition by the tools employed in this study (Brandon, Goldstein, & Ohman, 2016; Silva et al., 2018). This suggests that both visual and chemical identification of debris pieces may be needed to quantify and understand plastic ingestion in seabirds.

As expected, microplastics in Red Phalarope stomachs were largely PP and PE (Figure 2; Figure 3). Indeed, 42% of the ingested particles were identified as PE (Figure 2), 23% as PP, and 10% are

suspected to be co-polymers made of ethylene and propylene monomers. The majority of birds studied had ingested PP (5 out of 6 birds; Figure 3). Only one bird had ingested polystyrene (PS), and only one had ingested ethylene/polypropylene/diene monomer (EPDM). The most common polymers identified in the Red Phalaropes align with other studies of marine debris (Andrady, 2011; Browne, Galloway, & Thompson, 2010; Smith et al., 2018). As different plastic formulations result in differences in buoyancy, plastics are heterogeneously repartitioned throughout the water column (Cole, Lindeque, Halsband, & Galloway, 2011). Due to their respective densities, polymers such as PP and PE are prone to floating at the surface of the ocean, while PA and PS tend to sink. Polyvinylchloride (PVC) and polyester are most likely to be found at the bottom of the water column. Consequently, the larger proportion of PE and PP identified in the Red Phalaropes stomachs is consistent with previous studies in which it is observed that these birds mistake plastic debris for prey while surface feeding (Drever et al., 2018; Provencher et al., 2015). Moreover, Moser & Lee (1992) reported that Red Phalaropes also likely ingest denser plastics compared to other bird species, as PA and PS, where these polymers tend to be brought to the surface along upwelling areas. PE, PP and PS are three of the most demanded polymers on the market at a global scale (Hahladakis, Velis, Weber, Iacovidou, & Purnell, 2018), therefore they are most likely to be found as waste in the environment, corroborating our findings.

Based on FTIR analysis, 12% of the analysed particles are non-plastics (Figure 2) but a decision could not be reached for the remaining 10% of the particles, which are thus labeled “inconclusive” (Figure 2). We identified particles as “non-plastics” when they had an acceptable quality of spectrum but did not exhibit characteristic plastic features. At least four of the non-plastic particles were identified to likely be carbonate minerals, mainly dolomite. This is consistent with sightings of these birds on shore, and their tendency to ingest small rocks and pebbles to help break down food. In addition, one of the particles identified as non-plastic did not absorb IR radiation at all, despite being analyzed by two operators and on two different instruments. The presence of non-plastics would suggest a potential overestimation of the number of plastic particles during visual characterisation. Such an overestimation has been documented in previous studies (Shim et al., 2017; Silva et al., 2018; Zarfl, 2019; Zeng, 2018). We used the term “inconclusive” to designate particles believed to be plastics through visual examination, that could not be identified as either plastics or non-plastics following FTIR analysis.

Various factors could explain the inconclusive results, such as the poor quality of the spectra, or the lack of an exhaustive library. Poor quality spectra might be due to rough and abnormal particle shapes that inhibit good contact between the germanium ATR crystal and the sample surface. It is important to note that all of the particles were weathered (had rounded edges), suggesting an alteration of the material's surface. The particles may have been in the environment for years and were known to be exposed to the digestive tract of birds and thus exposed to weathering conditions. This weathering can make the analysis process particularly challenging as ATR-FTIR focuses on the object's surface: when the particle is weathered, it can impede proper contact with the instrument. In addition, the quality of the spectra might decrease in cases when interfering signals are present (Silva et al., 2018; Teuten et al., 2009). Weathering of plastics in oceanic conditions has been demonstrated to impact FTIR spectra (Brandon et al., 2016). In particular, the appearance of hydroxyl, carbonyl, and carbon-oxygen bonds has been demonstrated in weathered HDPE, LDPE, and PP (Brandon et al., 2016). Several of the samples analyzed in the present study did have bands that could be attributed to hydroxyl, carbonyl, and carbon-oxygen (c.f., Brandon et al., 2016). Few available libraries possess reference spectra of weathered polymers (Cai et al., 2019), consequently, good matches are more challenging to obtain, as the surface spectra of weathered polymers differ from virgin polymer standards. As previously discussed, plastic particles are likely to contain a variety of additives and to be composed of several polymers, further hindering analysis. Despite some documented analytical challenges with ATR-FTIR, chemical characterization is useful not only to access supplementary information about the type of polymer or the potential presence of additives, but also to produce reliable results regarding the amount of plastics ingested. While FTIR analysis is often referred to as a non-destructive analytical technique (Shim et al., 2017; Zarfl, 2019), weathered plastics are likely to be more fragile (Brandon et al., 2016), and several particles were destroyed when we analysed them indicating that they were indeed highly weathered. Thus, although reflectance and transmittance modes might be non-destructive, it is important to be aware that it is not the case for ATR mode, should this be a criterion when choosing an analytical method to characterize microplastics. Additional characterization could be performed in this scenario using techniques such as pyrolysis Gas Chromatography Mass Spectrometry (py-GCMS) or Raman spectroscopy (Hartmann et al., 2019; Shim et al., 2017).

The chemical identification of microplastic debris ingested by Red Phalaropes allows us to shed light on this particular exposure route to plastic-associated chemical contaminants. Indeed, different polymer types can be linked to various additives and sorbed environmental contaminants (Acampora et al., 2017; Avery-Gomm et al., 2018; Provencher et al., 2015; Rochman et al., 2019; Teuten et al., 2009). Chemical additives allow for the enhancement of polymer properties, along with increased durability of plastic products (Hahladakis et al., 2018). Consequently, sorbed or incorporated contaminants might be released into organisms following ingestion as the plastic gets partially degraded throughout the gastrointestinal tract. It has been observed that plastics sorb a variety of contaminants throughout their environmental weathering (Provencher et al., 2017; Rochman, Hoh, Hentschel, & Kaye, 2013). Among our particles, 71% of the plastics displayed signs of weathering-induced “yellowing” (Drever et al., 2018) (Table 1), which could suggest the potential for sorption of polychlorinated biphenyls (PCBs) during the aging process (Ogata et al., 2009). Although the release mechanisms of these chemicals into the organism following ingestion remain largely unknown, the high proportion of both PE and PP found in the Red Phalaropes stomachs raises questions about contaminant exposure and would suggest the need for further monitoring. Through the knowledge of their migratory patterns and variety of feeding modes, marine birds can be a valuable indicator of plastic pollution globally (Nevins et al., 2005).

This study contributes to the body of literature about plastic pollution in the north-eastern Pacific Ocean, and specifically the plastic pollution that marine birds are exposed to. Knowledge of plastic ingestion across Canadian seabird species, in particular, is very limited (Provencher et al., 2015). Our results are consistent with the findings of Desforges et al. (2014), who reported large amounts of microplastics closer to the shore of British Columbia. In addition, Williams et al. (2011) found a high occurrence of Styrofoam, plastic bottles and plastic bags during a survey of floating marine debris in the same geographic area. These objects are often made from PS and HDPE respectively, which corroborates the polymer types found in the Red Phalaropes’ stomachs. This indicates that a proportion of microplastics found at the surface of the ocean might originate from the decomposition of these plastic debris.

Our findings in this study, along with others reporting on plastic-related contaminants found in marine birds (Tanaka et al., 2013), or more broadly plastic ingestion (Poon, Provencher, Mallory,

Braune, & Smith, 2017) indicate the need for further monitoring as marine birds are undeniably exposed to plastic pollution. Only a few of the plastic ingestion studies published to date include details about the type of polymers encountered, yet polymer identification provides valuable information on the possible types of chemicals to which marine birds might be exposed as well as the types of plastics that are impacting seabirds. Polymer identification along with physical characteristics are valuable data that facilitate tracking plastic sources more broadly (e.g., Rochman et al., 2019). While opportunistic sampling of a small number of individuals offers an insight of the situation of exposure of Red Phalaropes to microplastic pollution, broader studies are necessary to assess the threat posed by microplastics and their associated contaminants to seabirds.

CONCLUSION

Seabirds are particularly vulnerable to marine plastic pollution. Here, we provide chemical characterization of particles found in the stomachs of dead Red Phalaropes, suspected to be plastics upon visual examination. All examined Red Phalaropes (n=6) had ingested polymers consistent with plastic debris, mainly in the form of microplastic fragments. However, following FTIR analysis, we reported a slightly lower level of ingested plastic than was estimated upon physical characterisation by Drever et al., (2018). We positively identified 79% of the examined particles as plastics, with the remainder of the particles remaining unidentified. Of the unidentified, we classified 10% as non-plastic based on the lack of spectral bands expected for plastic materials, and 11% were inconclusive and could not be identified as plastic with certainty. Of the plastic particles, the dominant polymer types were PE and PP. Ingestion appears to occur through the scavenging of floating plastics, ingested along with food. Our findings suggest that Red Phalaropes could be exposed to various contaminants such as polychlorinated biphenyls following plastic ingestion. Further analysis of these birds' liver and muscle tissue could provide additional details as to the level of threat this species, and other marine birds, are facing from microplastic-sorbed contaminants. Finally, the use of ATR-FTIR alone proved to have certain limitations, and consequently, we suggest using a combination of analytical techniques for future work to ensure all particles can be identified.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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AUTHOR CONTRIBUTIONS

Eloïse Teboul, Anna L. Harrison, Diane M. Orihel and Jennifer F. Provencher conceived the study. Laurie Wilson coordinated logistics regarding carcasses. Jennifer F. Provencher recovered the plastics and performed visual identification. Mark C. Drever analysed the initial data. Eloïse Teboul conducted the FTIR analysis and analysed the data. Eloïse Teboul wrote the manuscript, with contributions from all authors. All authors contributed to editing and revising. Diane M. Orihel and Anna L. Harrison acquired the funding.

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Table 1. Characterisation of 52 particles ingested by six (6) Red Phalaropes collected following a mortality event in the Fall 2016. Physical characterisation was performed by Drever et al., 2018 following the guidelines of Provencher et al., 2017. Confidence level that the examined particle is a plastic polymer was determined upon FTIR analysis coupled with physical characterisation. Polymer attribution is based upon algorithm matching in addition to manual comparison of acquired spectra to various libraries available.

Red Phalarope ID	Physical characterisation ¹			Chemical characterisation	
	User/industrial plastic	Type of particle	Pigmentation	Polymer attributed	Confidence level that the particle is a plastic polymer
Bird C WHN16-276	user	foamed	black	PP ²	Medium
	user	foamed	black	PP	High
	user	fragment	black	Inconclusive	Medium
Bird D WHN16-276	industrial	pellet	off white/clear	HDPE ³	High
	user	fragment	yellow	PP	High
	user	fragment	off white/clear	HDPE	High
	user	sheet	black	PA ⁴ or co PP-PE ⁵	High
	industrial	pellet	black	HDPE	High
	user	fragment	grey/silver	co PP-PE	High
	industrial	pellet	black	Inconclusive	Low
	user	rubber	black	HPDE	High
	user	rubber	black	PA or co PP-PE	High
	user	fragment	off white/clear	Non-plastic ⁶	None
	user	foamed	off white/clear	PS ⁷	High
	user	fragment	off white/clear	Non-plastic ⁶	None
	user	fragment	off white/clear	Non-plastic ⁶	None
	user	sheet	black	Non-plastic	None
	user	fragment	off white/clear	Non-plastic ⁶	None
Bird E WHN16-276	user	fiber	brown	PP	High
	user	fragment	brown	PA or co PP-PE	High
	user	fragment	black	PA or co PP-PE	High
Bird F WHN16-276	user	wax	off white/clear	PE ⁸	High
	user	fragment	orange/brown	LDPE ⁹	High
	industrial	pellet	orange/brown	Inconclusive	Low
Bird G WHN16-276	user	fragment	off white/clear	Inconclusive	Inconclusive
	user	sheet	orange/brown	PE	High
	user	fragment	yellow	PP	High
Bird I WHN16-277	user	fragment	off white/clear	PP	High
	user	fragment	off white/clear	HDPE	High
	user	fragment	off white/clear	PP	High
	user	fragment	off white/clear	Inconclusive	Inconclusive
	user	fragment	blue/purple	PE	High
	user	fragment	off white/clear	PE	High
	user	fragment	off white/clear	Non-plastic	None
	user	fragment	off white/clear	PE	High
	user	fragment	off white/clear	LDPE	High
	user	fragment	off white/clear	PP	Medium

user	fragment	off white/clear	HDPE	High
user	fragment	off white/clear	HDPE	High
user	fragment	off white/clear	PP	High
user	fragment	off white/clear	LDPE	High
user	fragment	off white/clear	PP	High
user	fragment	off white/clear	EPDM ¹⁰	Medium
user	fragment	off white/clear	PE	High
user	fragment	off white/clear	PP	High
user	fragment	off white/clear	PE	High
user	fragment	off white/clear	LDPE	High
user	fragment	off white/clear	PP	High
user	fragment	off white/clear	PE	High
user	fragment	off white/clear	PE	High
user	fragment	off white/clear	HDPE	High
user	fragment	off white/clear	PE	High

425

426 ¹ Data from Drever et al., 2018

427 ² Polypropylene

428 ³ High Density Polyethylene

429 ⁴ Polyamide

430 ⁵ Propylene-Ethylene copolymer

431 ⁶ Believed to be dolomite

432 ⁷ Polystyrene

433 ⁸ Polyethylene

434 ⁹ Low Density Polyethylene

435 ¹⁰ Ethylene/Propylene/Diene monomer

FIGURE CAPTIONS

Figure 1 Fourier Transform Infrared (FTIR) spectroscopy results of a representative panel of plastics found in Red Phalaropes stomachs. **a.** Spectrum collected using a Perkin Elmer micro-FTIR Spectrometer Spotlight 150ir in ATR mode. Resolution 8 cm^{-1} , 32 scans. Matched with High Density Polyethylene (correlation=0.91). **b.** Spectrum collected using a Perkin Elmer micro-FTIR Spectrometer Spotlight 150ir in ATR mode. Resolution 8 cm^{-1} , 32 scans. Matched with Polypropylene (correlation=0.80). **c.** Spectrum collected using a Bruker Alpha II FTIR in ATR mode. Resolution 4 cm^{-1} , 8 scans. Matched with Low Density Polyethylene (Hit Quality Index=743). **d.** Spectrum collected using a Bruker Alpha II FTIR in ATR mode. Resolution 4 cm^{-1} , 8 scans. Matched with an Ethylene-Propylene copolymer (Hit Quality Index=398). **e.** Suspected plastics isolated from Red Phalarope “D” following visual examination. **f.** Suspected plastics isolated from Red Phalarope “I” following visual examination.

Figure 2 Chemical identification of particles ingested by six Red Phalaropes using Fourier Transform Infrared spectroscopy. PP=polypropylene, PE=polyethylene, EPDM=ethylene/propylene/diene monomer, PA=polyamide, co PP-PE=polypropylene/polyethylene copolymer, PS=polystyrene. “Inconclusive” designates particles believed to be plastics through visual examination that have not been confirmed through FTIR analysis due to the poor quality of the spectra obtained (likely linked to particle weathering) and/or the lack of an acceptable library match. Inset: Distribution of polyethylene (PE) by type. Total of 22 plastics recovered from Red Phalaropes stomachs were identified as PE following ATR-FTIR analysis. Differentiation based on library matches and the method described by Jung et al, 2018. HDPE=High Density Polyethylene, LDPE=Low Density Polyethylene, PE=undifferentiated type of Polyethylene.

Figure 3 Relative distribution of plastic polymers ingested by Red Phalaropes. Total of 52 particles ingested by six birds. Polymer types identified using Fourier Transform Infrared spectroscopy. PP=polypropylene, PE=polyethylene, EPDM=ethylene/propylene/diene monomer, PA=polyamide, co PP-PE=polypropylene/polyethylene copolymer, PS=polystyrene.