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Microplastics in the diet of rehabilitated seals

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Abstract

Microplastics are a pollutant ubiquitous throughout the marine environment. They are known to be present in the food chain and the consequences of this are not yet fully understood. Trophic transfer of microplastics from low trophic level organisms has been observed in laboratory studies but studies of trophic transfer of microplastics in higher trophic level organisms are scarce and more research is needed in this area.

This study investigates the presence of microplastics in common seal (*Phoca vitulina*) scat collected from Seal Rescue Ireland and the presence of microplastics in the herring (*Clupea herengus*) fed to these seals to investigate the relationship between microplastics in the two species and their transfer across trophic levels. The scat samples were sieved and then chemically digested using potassium hydroxide to eliminate any biological material; similarly the herring gastrointestinal tracts were digested. The microplastics present were described, measured and quantified. Thirty-one of the 40 (77.5%) scat samples investigated contained at least one microplastic, with a total of 66 microplastics identified. 100% of the herring sampled (n=9) contained microplastics, with 73 microplastics identified. Microplastic fibres were more common than fragments, while a total of six colours of microplastics were identified. There was no statistical difference in the median length of microplastics found in the scat and herring samples. The findings suggest that trophic transfer is a potential pathway of microplastic ingestion in common seals but further studies are needed to confirm this.

Keywords

Microplastics, Scat, fibres, *Phoca vitulina*, *Clupea harengus*.

Highlights

- Microplastic occurrence is high in common seal scat samples.
- Microplastics are more abundant in herring samples than scat samples.
- Microplastic fibres are more common than fragments.
- There is no difference in microplastic median length recorded in herring and scat.

W.C. 290

1. Introduction

Large scale plastic production has increased rapidly since the 1950s (Geyer *et al.*, 2017) and is continuing to increase on a global scale (Willis *et al.*, 2018). Plastic is now one of the most commonly produced man-made materials in the world (Geyer *et al.*, 2017). This is because plastics are low cost, versatile and durable materials with a range of common uses such as single use food packaging, children's toys, household items and medical devices to name a few (Galloway, 2015). About 50% of plastic produced annually is single use plastic packaging (Mathalon & Hill, 2014) and it is estimated that up to 12.7 million metric tons of plastic waste is added to the world's oceans annually (Borelle *et al.*, 2017). This plastic travels across oceans in water and air currents, sometimes accumulating in oceanic gyres and/or settling in the benthic sediments (Borelle *et al.*, 2017). These plastics are now considered to be ubiquitous across all marine environments (Eriksen *et al.*, 2014). Plastic has also been documented as a problem in freshwater ecosystems (Provencer *et al.*, 2017). Plastics can cause serious harm to marine wildlife and marine ecosystems worldwide (Nelms *et al.*, 2019); for instance many species of marine fauna are known to become entangled in these plastics, these include seal, cetacean, seabird and turtle species (Eriksen *et al.*, 2014). This entanglement often leads to the death of the animals by drowning, infection from injury or starvation (Gregory, 2009).Marine fauna are also known to ingest plastic debris mistaking it for food; this often leads to starvation and death as they are unable to digest the plastics (Pawar *et al.*, 2016). Plastics are usually divided up into a range of size categories, these are; megaplastics (>100mm diameter), macroplastics (>20mm), mesoplastics (5-20mm), microplastics (<5mm) and nanoplastics (<100nm) (Barnes *et al.*, 2009, Koelmans *et al.*, 2015).

First described by Thompson *et al.*, (2004) microplastics are defined as plastic pieces which are <5mm in length (Lusher *et al.*, 2013). Records of microplastics in the sea go back as far as the 1960's and have been increasing in abundance since then (Thompson *et al.*, 2004).They have been recorded across all oceans including remote regions such as deep sea and polar regions(Eriksen *et al.*, 2014, Wang *et al.*, 2018).As many as 124 microplastics have been found per litre of sea water off of the coast of Portugal (Browne *et al.*, 2011).There are many sources of microplastics; primary microplastics are microplastics which were originally manufactured to be <5mm in length, these include microbeads used in cosmetics and synthetic clothing fibres as well as plastic pellets used for manufacturing (GESAMP, 2015, Siegfried *et al.*,2017). Secondary

microplastics are made from the breakdown of larger plastics (GESAMP, 2015); these large plastics are broken down by wave action, weathering and UV exposure (Foekema *et al.,* 2013). Once microplastics enter the marine environment they persist and are impossible to remove from the environment (Lusher *et al.,* 2014).

There are many concerns about the presence of microplastics in the environment, as they are so small they are extremely bioavailable to marine life (Nelms *et al.,* 2019). Approximately 220 animal species have been recorded to ingest microplastics in the wild (Smith *et al.,* 2018) these include species of zooplankton, fish, seabirds and marine mammals (Nelms *et al.,* 2019). There are many ways microplastics can be ingested; they may be accidentally ingested directly using filter feeding or indirectly due to trophic transfer of microplastics from prey (Nelms *et al.,* 2019). It has been suggested that the microplastics ingested by fish are mainly of similar colour and shape as their food sources (Foekema *et al.,* 2013).As there is a wide range of colours, sizes and shapes of microplastics it is likely they mimic a variety of natural food sources of marine life (Foekema *et al.,* 2013). Research on European perch (*Perca fluviatilis*) has shown that some microplastics are more attractive than food (Wang *et al.,* 2018). Microplastics may also enter the body by passing across the gills if they are less than 40μm in size (GESAMP, 2015). The ingestion of microplastics has been shown to alter species behaviour and function, for example, by causing a reduction in food intake as well as impairing reproduction and development (Borelle *et al.,* 2017). If microplastics accumulate within organisms digestive systems in high numbers they have the potential to clog digestive systems (Lusher *et al.,* 2013). As well as this, they have the potential to cause abrasions and injuries to the digestive system (Wright *et al.,* 2013).Damage has also been recorded to brain and intestinal function in laboratory studies of low trophic level organisms (Nelms *et al.,* 2019). In addition due to their high surface area to volume ratio and their hydrophobic qualities microplastics are known to adsorb and concentrate chemical contaminants in sea water including persistent organic pollutants such as polychlorinated biphenyls (PCBs) onto their surface (Kwon *et al.,* 2017, Nelms *et al.,* 2019, Woodall *et al.,* 2015). These chemicals are known to cause adverse health effects and death in marine biota as they are able to transfer into organisms tissues and organs after ingestion (Erikson *et al.,* 2014, Stalling & Mayer, 1972).This could be a danger not only for the individual lower trophic organisms ingesting microplastics but it could also have consequences for higher trophic levels as many of these contaminants have the potential for biomagnification (Lusher *et*

al., 2013). It has been suggested that there could be a relationship between the cause of death in marine mammals and microplastic abundance, as examination of stranded marine mammals in the UK found that animals that died as a result of infectious disease also had a higher occurrence of microplastics in their digestive tracts than animals that showed signs of death from trauma (Nelms *et al.,* 2019). Further research is needed on this possible relationship.

Seal Rescue Ireland is a seal rescue and rehabilitation centre in Courtown, Co. Wexford. It is the only seal rescue facility in Ireland and takes in sick, injured and orphaned grey (*Haliochoerus grypus*) and common seal pups from all over the country. When pups are initially admitted to Seal Rescue Ireland they are tube fed in the intensive care units until they are strong enough to start eating fish themselves individually. They then feed freely on herring in bathtubs in the kennels until they are eating well enough to go out to pools and compete with the other seals for their fish. Herring is fed to these pups as it is a fish high in fat and it helps them to gain weight quickly, it also makes up a large portion of their diet in the wild (Luxa & Acevedo-Gutiérrez, 2013). Herring is a species known to contain microplastics in the wild (Beer *et al.,* 2018). The pups are rehabilitated in the centre and released back into the wild when they are healthy and fit enough to survive alone.

Much of the research into the presence and effects of microplastics is limited to low trophic level species which can be kept in laboratories or stranded marine megafauna (Nelms *et al.,* 2019).This study aimed to investigate the presence of microplastics in seal scat collected from common seal pups in rehabilitation at Seal Rescue Ireland. If microplastics were present in these scats the study also aimed to quantify the abundance of microplastics by size, shape and colour. The presence of microplastics in the herring being fed to the seals was also investigated to determine the relationship between the transfer of microplastics across trophic levels.

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2. Materials and Methods

2.1 Scat collection

Seal scat was collected from seals being rehabilitated in Seal Rescue Ireland. This facility is located in Co. Wexford at 52°38’56.83” N, 6°13’42.23” W. Scats were collected from eight common seals in the rehabilitation centre over a period of six weeks. These seals were in the rehabilitation centre for a number of weeks before scat collection began to minimise chances of

contamination to the experiment from exposure to plastic litter items in the wild. Scats were collected from the kennels, which are covered structures, using a metal spoon and placed in aluminium foil. These scats were labelled and stored in a freezer at -18°C until they could be analysed.

2.2 Scat sample preparation

Scats were left overnight to thaw at room temperature (n=40). Work surfaces were cleaned using alcohol following the protocol of Lusher *et al.,* (2016). The scats were individually passed through four brass nested sieves with woven stainless steel wire mesh sized 710µm, 300µm, 250µm and 180µm, each scat was placed on the top sieve and rinsed through using filtered water and a natural fibre paintbrush. The hard prey remains from the top three sieves were removed and placed in vials containing 70% ethanol for a diet study. Exposure of the samples to the air was minimised and the remaining contents of the 180µm sieve were placed in a glass jar sealed with a metal lid which had been washed with prefiltered water; the samples were then weighed and labelled.

2.3 Chemical digestion

A 10% potassium hydroxide (KOH) solution was prepared using prefiltered water and was left to settle and cool down for at least 15 minutes before use (Lusher & Hernandez-Milian, 2018). The KOH was then added to the scat samples, the amount added was approximately 3 times the volume of the scat collected (Foekema *et al.*, 2013). The samples were covered with parafilm to prevent contamination and evaporation as KOH is known to react with metal. Samples were stored in the fumehood and agitated daily to aid digestion (Lusher & Hernandez-Milian, 2018). When the biological material was digested the samples turned a clear or yellow colour (Lusher & Hernandez-Milian, 2018). As the samples were of different sizes and consistency the time needed for digestion varied between 2 and 8 weeks.

The digested samples were filtered using a Büchner filtration system with a porcelain funnel and Whatman 1001-125 Grade 1 Qualitative Filter Papers. After being filtered the samples were stored in petri dishes with aluminium foil lids to prevent airborne contamination. Exposure of the samples to air was again minimised during this process to prevent airborne contamination.

2.4 Fish dissection and digestion

A subsample of the herring used to feed the seals was also collected from Seal Rescue Ireland, these were stored in a freezer at -18°C until they could be analysed (n=9). These fish were caught in the Northeast Atlantic off the Northwest coast of Ireland. As before, surfaces were cleaned with alcohol prior to starting work, any instruments and equipment to be used for the dissection and manipulation of the fish were also cleaned and checked for airborne fibres under a Nikon SMZ645stereo microscope with an external light source (Lusher *et al.,* 2016).

The herring were measured and weighed before dissection. Each fish was cut from the anal slit to the gills on a wooden board. Using a blunt metal forceps the flesh was moved back to show the gonads and digestive system, the fish were then sexed. The end of the large intestine was cut at the anal slit and the oesophagus was also cut using a scissors. Any unnecessary tissue such as the pancreas was removed and care was taken not to puncture the stomach. The gastrointestinal tract (GIT) made up of the oesophagus, stomach, pyloric ceca and intestines (Nelms *et al.,* 2018) was then placed onto, and wrapped in, aluminium foil. These samples were labelled and stored in the freezer at -18°C until they could be analysed.

The samples were thawed overnight at room temperature. The contents of the stomach were first viewed under a Nikon SMZ645stereo microscope with an external light source; this was done under a laminar flow hood. Any hard prey remains in the samples were removed and stored in vials containing 70% ethanol for preservation. Any plastics found in the samples during this initial investigation were also removed with forceps and stored in a clean glass petri dish for further examination.

The GITs were weighed and placed in glass beakers that had been washed with prefiltered water. KOH was added to these beakers at approximately 3 times the volume of the stomach (Foekema *et al.,* 2013). As with the scats the samples were covered with parafilm and left in the fumehood to digest and were agitated at regular intervals.

When digestion was complete the contents of the beakers were filtered using a Büchner filtration system with a porcelain funnel and Satorius Glass-Microfibre 47mm Grade MGC filter paper. These filter papers were stored in clean glass petri dishes until they could be viewed under the microscope.

2.5 Microscope identification

The filter papers were viewed under a Nikon SMZ1000 stereo microscope with an external light source in a clean laminar flow hood to avoid airborne contamination. Any microplastics present on the filter papers were picked out using a size 4 forceps and transferred to a cavity slide. These slides were viewed under a Leica DM500 compound microscope with a Leica ICC50 E camera attachment. All microplastics were photographed and their length and width were measured using ImageJ software. Colour was also recorded at this stage and the microplastics were classified as either fragments or fibres.

2.6 Contamination control

A number of steps were taken to minimise contamination of the samples. All samples were collected and stored in the freezer in aluminium foil to avoid contact with plastic. Cotton clothing was worn at all times in the lab to avoid contamination of the samples and a white lab coat and white gloves were also worn (Woodall *et al.,* 2015). Although use of plastic equipment was kept to a minimum any plastic equipment used was white or clear so that white fibres could be eliminated if large amounts showed up, a list of any plastics which could come in contact with the samples was also kept (Woodall *et al.,* 2015). All lab surfaces were cleaned with alcohol before starting any lab work (Lusher *et al.,* 2016). All instruments used were cleaned with prefiltered water prior to use and checked under a Nikon SMZ645stereo microscope with an external light source for any airborne fibres (Lusher *et al.,* 2016). Exposure of the samples to air was limited as much as possible to avoid airborne contamination (Woodall *et al.,* 2015). A 7μm filter was added to the water source used to sieve the scats to remove any potential contamination (Lusher *et al.,* 2018). Environmental monitoring was conducted by dampening a Whatman 1001-125 Grade 1 Qualitative filter paper in a petri dish with prefiltered water, this was left exposed during sample processing (Woodall *et al.,* 2015).

2.7 Data analysis

Data analysis was conducted using IBM SPSS Statistics 25 software. The data were tested for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Kruskal-Wallis tests were used to investigate differences in median microplastic length between scats and herring GITs and to examine the relationship between median length and colour. Post-hoc tests using the Bonferroni

correction for multiple tests were conducted as necessary following the Kruskal-Wallis tests in SPSS. The proportion of microplastics of different colours was examined using a Chi squared test.

2.8 Feasibility study

As scats take a long time to digest a test was carried out to see if the plastics degrade while being in KOH for an extended period of time. Ten blue plastic fishing line pieces were placed in a cavity slide and viewed under a Leica DM500 compound microscope with a Leica ICC50 E camera attachment. Pictures were taken of these plastics and they were measured using ImageJ software. These plastics were placed in a beaker with 10% KOH and left in the fume hood and were agitated daily for 6weeks. This was then filtered using a Büchner filtration system with a porcelain funnel and a Satorius Glass-Microfibre 47mm Grade MGC filter paper. After filtering these plastics were again viewed under a Leica DM500 compound microscope with Leica ICC50 E camera attachment. Pictures were taken and the plastics were measured again using ImageJ software to compare the sizes and colour of the plastic before and after 6 weeks in KOH. A Wilcoxon matched pair signed-rank test was used to analyse the difference in length of the plastics before being placed in KOH and after 6 weeks in KOH. As the sample size was under 30 a Wilcoxon matched pair signed-rank test was also used to analyse the difference in the width of the plastics before and after being placed in KOH for 6 weeks.

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3. Results

3.1 Microplastic abundance

At least one microplastic was identified in 77.5% of the seal scats sampled. A total of 67 plastics were identified in the 40 scats, 66 of these plastics were <5mm and could be defined as microplastics, 1 plastic piece found was classified as a mesoplastic. The average number of microplastics found per scat was 1.65, ranging from 0 to 5 microplastics. All of the microplastics found in the scat samples were identified as fibres (see Figure 1).

At least one microplastic was found in all of the herring GITs sampled (100% occurrence). Of the 74 plastics identified in the nine fish, 73 of these plastics were <5mm and 1 mesoplastic was found. The average number of microplastics found per GIT was 8.11 with numbers ranging from

4 to 13 microplastics/GIT. Almost all (97.26%) of the microplastics found in the GIT samples were identified as fibres; in addition, one fragment was found and one microplastic which could not be classified as a fibre or a fragment was found, this was classified as "other".

As the focus of this study was microplastics any mesoplastics identified were recorded but not included in the statistical analysis.

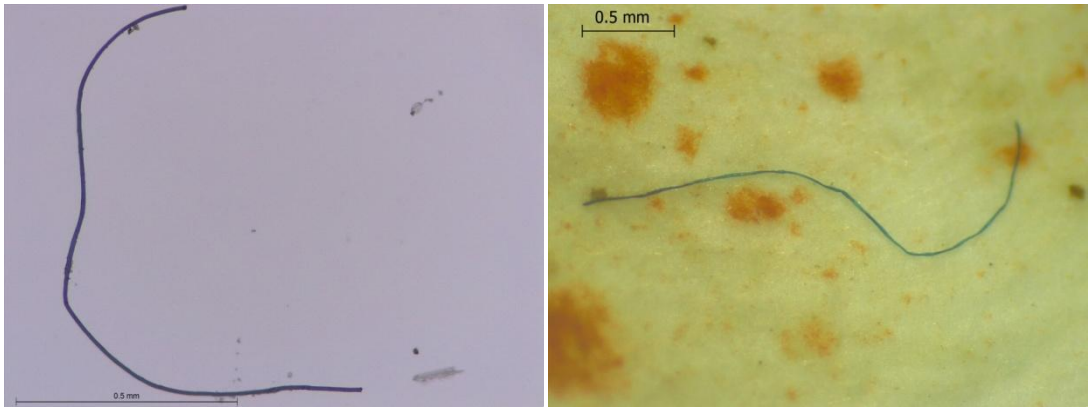

Figure 1: Examples of microplastics found in *(a)* scat samples and *(b)* herring GITs

3.2 Size

The majority of plastics found in the scat samples were between 1.01-1.50mm in length (figure 2) and the mean length of microplastics found within the scat samples was 1.46mm (±1.02 SD). The most frequently occurring length of plastics found in the herring GIT samples was between 0-0.5mm (figure 2) while the mean length of microplastics found within the herring GIT samples was 1.21mm (± 0.92 SD). The majority of plastics identified within the environmental controls were between 0.51-1.0mm in length (figure 2) and the mean length of microplastics found in the environmental controls was 1.80mm (±1.27 SD). The smallest microplastic identified across all the samples was 0.045mm in length; this was found in a herring GIT sample. The largest microplastic identified was 4.964mm in length and was found in the environmental control. The largest mesoplastic found was 13.916mm in length and this was also found in the environmental control.

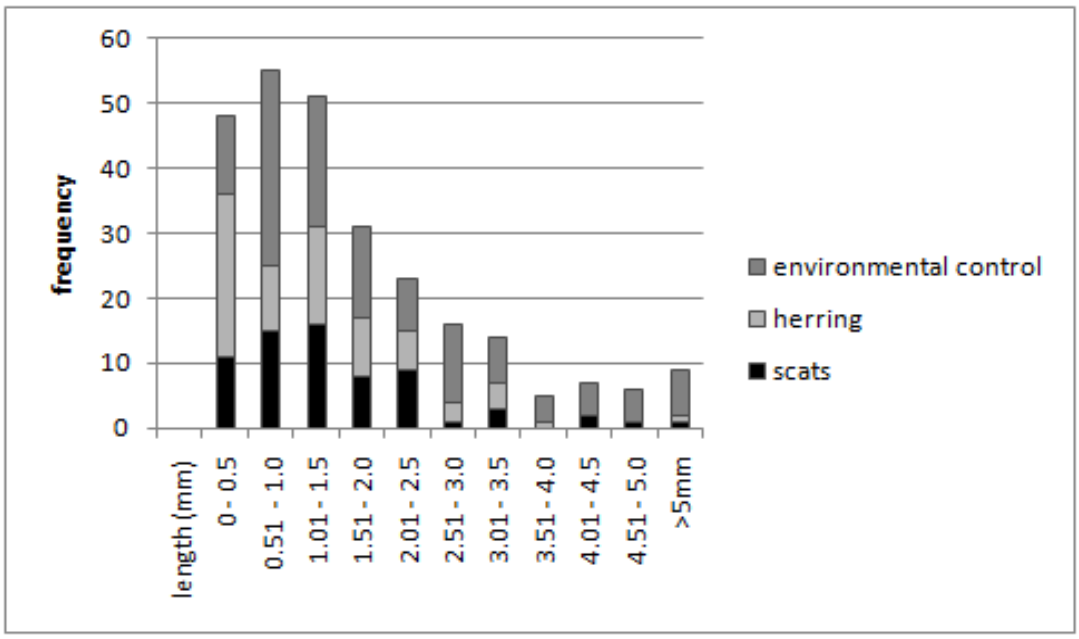

Figure 2:Length frequency distribution of all plastics found during the study grouped by source.

There was a statistically significant difference in the median length of the microplastics across all three groups (Kruskall-Wallis, $p<0.006$). The post-hoc analysis showed that the statistically significant differences in length of the microplastics was between the microplastics found in the herring GITs and the environmental control (Bonferroni correction for multiple tests, $p<0.004$).

3.3 Colour

A total of six colours of microplastics were found across the scat and herring GIT samples. Black was the most commonly occurring colour across all three sources with a total of 177 black microplastics identified, followed by blue (n=57). One purple microplastic was identified, in the scat samples and one silver microplastic was identified in the herring GIT samples (figure 3). To test whether colours were found in the same proportions in the three sources of microplastics a Chi-square test was carried out. The results of this test ($\chi^2(10)= 23.2$, $p<0.05$) suggest that there are statistically significant differences in the proportion of colours.

Any plastic equipment used throughout the study was white or clear (table 1). No white or clear microplastics were identified within the samples (figure 3).

Table 1: List of all plastic equipment and its colour used throughout the study.

Equipment	**Colour**
Plastic Ruler	White
Gloves	White
Petri Dish	Clear
Polyester Labcoat	White
Parafilm	Clear
7µm Nylon Mesh	White

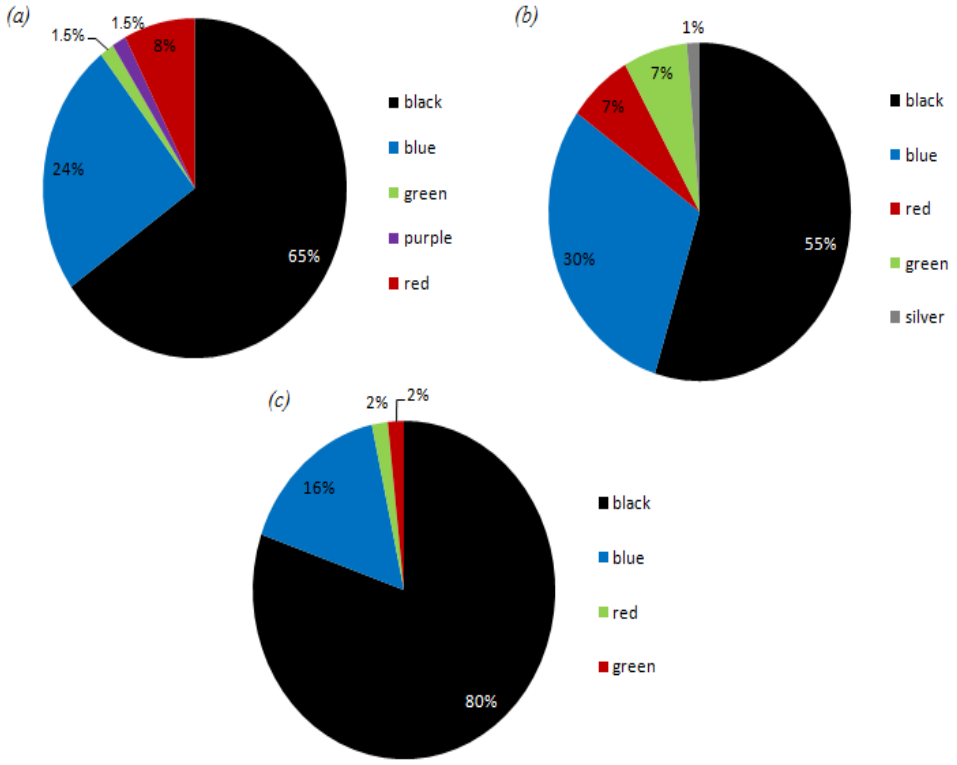

Figure 3: Proportions of microplastic colour in *(a)* scat samples, *(b)* herring GIT samples and *(c)* environmental controls.

There was no statistically significant difference in the median length of the six different microplastic colours (Kruskall-Wallis, p=0.244); the length frequency distribution is illustrated in figure 4.

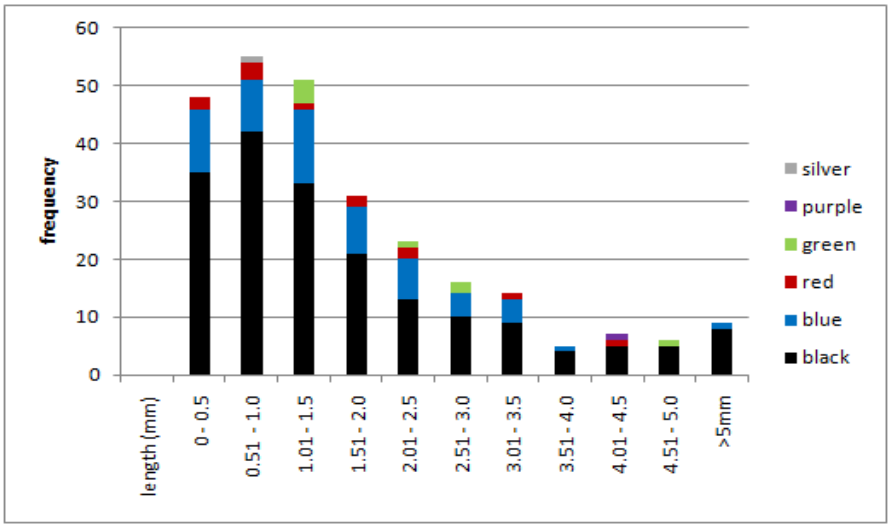

Figure4: Length frequency distribution of all plastics found during the study grouped by colour

3.4 Feasibility study

Two tests were carried out to investigate if the microplastics degrade while in KOH. The first test looked for differences between the length of the microplastics before and after 6 weeks in KOH. There was no significant difference between the lengths at the start and end of the experiment ($p=0.719$, $p>0.05$). The second test looked for differences between the width of the microplastics before 6 and after weeks in KOH and the width of microplastics. Again no significant difference was found between the widths at the start and end of the experiment ($p=0.618$, $p>0.05$). No colour change was recorded in the microplastics after 6 weeks in KOH.

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4. Discussion

77.5% of scats sampled in this study contained at least one microplastic. Although published data of the occurrence of microplastics within seals is rare, this result is not inconsistent with the published studies. 100% of herring GITs sampled in this study contained at least one microplastic. As fish were sourced directly from the fishing industry, they were not collected using the usual scientific protocols for microplastic studies (Nelms *et al.*, 2018). This means that these results may not be totally representative of the abundance of microplastics in herring, as microplastics may accumulate in fishing nets and can be ingested while the fish are trapped in

the net (Lusher *et al.*,2013). Many fishing nets are made from plastic materials; these may also break into microplastics which may be consumed by the trapped fish (Lusher *et al.,* 2013). More accurate results may also have been obtained if it had been possible to obtain a larger subsample of herring used in the rescue centre. Despite these samples being sourced from the fishing industry similar microplastic occurrence levels have been found in studies of microplastics in fish, for example Wieczorek *et al.,* (2018) found a 100% occurrence of microplastics in a species of Bristlemouth fish (*Gonostoma dendatum*) and a 93% occurrence in a species of deep-sea eel (*Serrivomer beanii*).

The majority of microplastics found in the scat samples were between 1.01-1.50mm in length, this is similar to the finding by Lusher *et al.* (2013) where the most common size class found in pelagic and demersal fish from the English Channel was 1.0-2.0mm. In contrast, the most frequently recorded size class found within the herring GIT samples was 0-0.5mm. However, there was no significant difference in length of microplastics recorded in the scat samples and herring GITs; this suggests that the microplastics found within the scat samples may have been present due to trophic transfer from the herring fed to the seals in Seal Rescue Ireland. It also supports findings from previous studies that microplastics are transitionary and are not permanently retained within the digestive system of marine mammals (Nelms *et al.,* 2019). The mean number of microplastics found in the herring GITs was 8.11 while the mean number found in the scat samples was 1.65 per scat. As there is, on average, a higher number of microplastics in the fish being fed to the seals than in the seal scat samples this suggests that while microplastics may not be permanently retained in the digestive systems of the seals they may temporarily be retained in them. Feeding trials in grey seals have shown that plastics have a slower passage time than natural substances such as fish bones and otoliths (Nelms *et al.,* 2019). It also has been suggested that the stomachs of marine mammals may be the site of temporary retention of microplastics (Nelms *et al.,* 2019).

There was a significant difference in the length of the microplastics found in the herring GITs and the environmental controls, this suggests that the microplastics found within the herring GITs did not come from the environment while processing the samples and were ingested by the herring. There was no significant difference in the length of microplastics recorded between the microplastics found in the scat samples and the environmental controls; this suggests that some fibres found within the scat samples may have come from the environment when the scats were

exposed to the air during the sieving stage of the study. It has been reported that the use of some chemicals to remove biological material from microplastics may cause damage to the microplastics present in the samples (Lusher *et al.*, 2017). As there was no significant difference in the size of the microplastics between the start and the end of the feasibility study and no colour change was recorded it can be concluded that the KOH did not cause the microplastics to degrade. As a result of this it can be assumed that the KOH did not affect the size or colours of the microplastics present in the scat and herring GIT samples and the microplastic abundance within the samples was not underestimated. Although this method of chemical digestion was successful and did not affect or degrade the microplastics present in the samples, it was a slow process to digest the scat samples due to the levels of biological material present in them, with some scat samples spending up to 8 weeks in KOH. In a study of the presence of microplastics in grey seals, Nelms *et al.*, (2018) overcame the time consuming digestion of scat samples by using an enzymatic digestion. It was reported that this method also had no effect on the physical characteristics of microplastics present in the sample (Nelms *et al.*, 2018).

The majority of plastics identified in this study were fibres, this corresponds with previous studies on microplastics in marine life (e.g. Lusher *et al.*, 2013, Lusher *et al.*, 2015, Mathalon & Hill, 2014, Nelms *et al.*, 2018, Wieczorek *et al.*, 2018). It has been suggested that fibres have the capability to accumulate together within digestive tracts of marine organisms with the potential to ultimately cause a blockage within the digestive tract (Wright *et al.*, 2013).

The colour of microplastics found within the scat samples and fish samples varied, black, blue, red and green were found in both samples in that (descending) order. In addition, a purple microplastic was found in the scat samples and a silver microplastic was found in the herring GITs. The difference in the proportion of colours found may have been caused by a number of reasons; for instance there may be huge diversity within the colours and types and amounts of microplastics found across the marine environment at different areas and times (Amélineau *et al.*, 2016) and the herring examined for microplastics may have been caught at a slightly different time or area to the herring being fed to the seals while scat collection took place. Although there was a significant difference in the proportion of the colours found in the scats and herring GITs, there was no relationship between the length distribution of the microplastics and the colour (figure 4). Black followed by blue as the most common colours found and this also

corresponds with other studies of microplastics within marine life (Lusher *et al.,* 2013, Nelms *et al.,* 2019, Wieczorek *et al.,* 2018).

Although plastic debris in the oceans has been listed as one of the main three emerging environmental concerns (UNEP, 2011) there is very little research in plastic and microplastics ingestion in high trophic marine predators (Nelms *et al.,* 2018). Fulmars (*Fulmarus* glacilis) are usually used as indicators of litter and plastic debris due to their wide distribution but they are not present across all European seas (Bravo Rebolledo *et al.,* 2013). Seals have also been suggested as indicators of plastic debris (MSFD, 2013) but there has been very little research conducted on the ingestion of plastics and microplastics by seals (Bravo Rebolledo *et al.,* 2013). Eriksson & Burton (2003) studied the occurrence of "small plastics" (>0.5mm) in the scat of Antarctic fur seals (*Arctocephalus spp.*) and found these plastics present in 100% of scats sampled. Bravo Rebolledo *et al.,* (2013) studied plastics in common seals, however this study did not focus solely on microplastics and the methods used to isolate the plastics within the scat samples was deemed inappropriate as they damaged the plastic. More recently, Nelms *et al.,* (2018) became the first to study the abundance of microplastics in grey seals, this was conducted by collecting scat samples from seals at the Cornish Seal Sanctuary. Microplastics were present in 48% of the scat sampled (Nelms *et al.,* 2018). This is the only study known to demonstrate the transfer of microplastics across trophic levels from fish to top predators in the marine environment (Nelms *et al.,* 2018).

Microplastics have been found in nearly all marine habitats worldwide (Lusher, 2015). Although it is known that microplastics can cause harm to wildlife, the full extent of harm and effects of microplastics are still unknown (Critchell & Hoogenboom, 2018). As microplastics appear to be impossible to remove from the marine environment and constantly being added to the world's oceans further research must be carried out on the movement of microplastics across the trophic levels. While the results of this study show that we cannot be certain that all of the microplastics present in the scat samples were due to trophic transfer; they do suggest that microplastics are in the food chain and may be transferred across trophic levels. This is similar to previous findings of trophic transfer of microplastics across a range of species (Farrell & Nelson, 2013, Nelms *et al.,* 2018). The number of plastics being fed to the seals may be underestimated as this study focused on the GITs of the herring but it has been shown that microplastics have the capability to move into other organs and tissues of fish (Pittura *et al.,* 2018, Smith *et al.,* 2018). Access to a

Fourier Transform (FTIR) imaging system would allow for more accurate results of the sources of the microplastics as FTIR spectroscopy provides information on the materials and the chemical bonds between the different particles (Shim *et al.,* 2017). The use of this technology is widely used across microplastic studies and would confirm materials to be plastic and identify polymer types (Jung *et al.,* 2018*).* The polymer types found in the scat, herring GIT and environmental control samples could be analysed and compared, this would give a better idea of the source of microplastics found during this study. Sieving the scats underneath a positive laminar flow hood would also allow for more accurate results as the potential for environmental contamination during the processing of the scats would be removed.

This study was the first of its kind to focus on microplastic occurrence in common seal scat and their trophic transfer. It can be concluded that although it is likely the microplastics in the scat were present due to trophic transfer from the herring that the seals are fed it cannot be confirmed due to the potential sources of error discussed. It is important that further studies are carried out on the presence and transfer of microplastics across trophic levels in the marine ecosystem to obtain more accurate results as microplastics are an environmental threat with risks which are not yet fully understood (Kramm & Völker, 2018).

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