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Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel

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ABSTRACT

Microplastics are present in marine habitats worldwide and laboratory studies show this material can be ingested, yet data on abundance in natural populations is limited. This study documents microplastics in 10 species of fish from the English Channel. 504 Fish were examined and plastics found in the gastrointestinal tracts of 36.5%. All five pelagic species and all five demersal species had ingested plastic. Of the 184 fish that had ingested plastic the average number of pieces per fish was 1.90 ± 0.10. A total of 351 pieces of plastic were identified using FT-IR Spectroscopy; polyamide (35.6%) and the semi-synthetic cellulosic material, rayon (57.8%) were most common. There was no significant difference between the abundance of plastic ingested by pelagic and demersal fish. Hence, microplastic ingestion appears to be common, in relatively small quantities, across a range of fish species irrespective of feeding habitat. Further work is needed to establish the potential consequences.

1. Introduction

Marine debris contaminates the world's oceans from Polar Regions to the equator (Gregory and Ryan, 1997; Barnes et al., 2009; Zarfl and Matthies, 2010), and is found floating at the sea surface (Ryan and Moloney, 1993; Barnes and Milner, 2005), on the seafloor (Galgani et al., 2000) and on shorelines (Barnes and Milner, 2005). Plastic materials are the most common making up 60–80% of all marine debris (Gregory and Ryan, 1997). This form of contamination is of concern because it presents a threat to wildlife and can have important economic impacts on fisheries (Ryan et al., 2009). The impacts of large items of marine debris (macroplastics) on the marine environment have been widely reported (see previous reviews by Laist, 1997; Derraik, 2002). A range of marine taxa, including birds, sea turtles and marine mammals, are known to be affected by entanglement and ingestion, with consequences including impaired movement, decreased feeding ability, reduced reproductive output, lacerations, ulcerations and death (Laist, 1997; Derraik, 2002; Moore, 2008; Gregory, 2009).

Microplastics were first described by Thompson et al. (2004) who reported the occurrence and presence of plastics around 50 μm in size on shorelines and in the water column. Use of this term has been extended to include all items of plastic debris that are smaller than 5 mm in size (Arthur et al., 2009). Microplastics can enter the marine environment directly as granules used for air blasting, pellets and powders which are used for production of larger plastic products and abrasive scrubbers in cosmetics and cleansing products (Fendall and Sewell, 2009; Thompson et al., 2009a,b), and indirectly from the breakdown of larger plastic items as a result of photo-degradation, oxidation and mechanical abrasion (Andrady, 2003, 2005; Browne et al., 2007; Thompson et al., 2009a).

Studies over the past decade have shown that microplastics are widespread in the marine environment, at the sea surface, on shorelines and on the sea bed and that their abundance has increased since the 1960s. Because of their small size, microplastics have the potential to be ingested by a wide range of marine organisms. Laboratory studies have shown that invertebrates: crustaceans, barnacles, polychaete worms, mussels and amphipods, will ingest microplastic fragments (Thompson et al., 2004; Browne et al., 2008; Graham and Thompson, 2009). Whereas there have been fewer studies documenting the ingestion of microplastic in the natural environment (but see: Eriksson and Burton, 2003; Boerger et al., 2010; Murray and Cowie, 2011).

Microplastic ingestion has been documented in a selection of marine organisms. Recent work showed that 83% of Norway lobsters, *Nephrops norvegicus* (Linnaeus, 1758) collected in the Clyde Sea had ingested plastic including monofilament line and fragments of plastic bags (Murray and Cowie, 2011). Microplastic could have both physical and chemical effects on the organisms that ingest them. If ingested, microplastics may pass through the gut or may be retained in the digestive tract (Browne et al., 2008). Fibres may knot or clump and could be hazardous if they block feeding appendages or hinder the passage of food. Hoss and Settle (1990)

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suggested that if plastic particles were accumulating in high numbers in the intestines of smaller animals, they may have a similar effect to larger items of debris and clog digestive systems (Derraik, 2002; Gregory, 2009; Ryan et al., 2009). The accumulation of debris in the digestive tract may also cause a false sense of satiation leading to decreased food consumption (Ryan, 1988).

There is also concern that, if ingested, small items of plastic debris might facilitate the transport of chemical contaminants to organisms. Two mechanisms have been suggested, the release of chemical additives such as plasticisers incorporated during manufacture and the accumulation and subsequent release of persistent organic pollutants from sea water (Mato et al., 2001; Teuten et al., 2009). For example, plasticisers such as bisphenol-A (BPA) which are used in a range of plastic products can affect the hormonal systems and reproductive output of molluscs, fish, crustaceans and insects (Endo et al., 2005; Teuten et al., 2007; Oehlmann et al., 2009). Ingestion of microplastics by individual organisms at lower trophic levels could also have consequences for organisms at high trophic levels if any contaminants that are transferred have the potential for biomagnification (Teuten et al., 2009).

Despite these concerns, there have been few studies specifically examining the occurrence of microplastic in natural populations. The data that is available is for larger fragments of microplastics 1–5 mm (e.g. Day et al., 1985; van Franeker, 1985; Laist, 1997; Jackson et al., 2000; Pinnegar, 2009) and there is little data on the occurrence of pieces <1 mm. Early work identifying the ingestion of plastic by fish included Carpenter et al. (1972) who described pieces <16 mm in Atlantic silversides, *Menidia menidia* (Linnaeus, 1766). In addition, Hoss and Settle (1990) reviewed previous papers finding pieces <50 mm in the European flounder, *Platichthys flesus* (Linnaeus, 1758). More recent studies have been carried out in the North Pacific Gyre which is known to have substantial accumulation of debris (Moore et al., 2008). Boerger et al. (2010) found that microplastics (<2.79 mm) were consumed by fish feeding in the water column. In addition, Davison and Asch (2011) found mesopelagic fish to have ingested plastic fibres, filaments and films (mean length 2.2 mm). A recent study on plastic ingestion by catfish from estuarine waters in Western South Atlantic found all ontogenic phases of the three species of catfish ingested plastic (Possatto et al., 2011). However, few studies have formally identified the material found using fourier transform infrared spectroscopy (FT-IR). This is considered essential to conform the identity of pieces <1 mm.

The primary aim of this study was to describe the types of microplastic ingested by fish collected from the English Channel. With a secondary aim being to determine whether there were differences, in the frequency of microplastics, between in pelagic and demersal fish. The following specific questions were examined: (1) establish whether fish collected in shallow water habitats in the English Channel had ingested microplastics; (2) if so to identify what polymers were present; and (3) to assess whether the quantity of plastic ingested by fish varied between pelagic and demersal species.

2. Materials and methods

Fish were collected from coastal waters 10 km southwest of Plymouth, UK (50° 16N, 004° 15W) during routine Marine Biological Association (MBA) standard haul trawls. The standard haul is part of the long term fisheries sampling carried out at the MBA since 1913. Note that since these trawls are designed to catch fish the mesh size at the cod end was 70–75 mm (Genner et al., 2010); therefore unlike studies of fish collected from plankton nets (e.g. Boerger et al., 2010) it is extremely unlikely that any of the plastics found in the fish examined here (maximum size 14.3 mm – see results) had accumulated in the net and been ingested by fish whilst in the net itself. Plastic used in the construction of the net was examined so as to ensure that fragments of the net were not a potential source of any of the material found in the fish. Sampling occurred at station L4 which is most consistently sampled (Genner et al., 2010). Samples were obtained during June 2010 and July 2011 at an average depth of 55 m. The 10 species of fish used in this analysis, were five pelagic species (whiting *Merlangius merlangus* (Linnaeus, 1758); blue whiting *Micromesistius poutassou* (Risso, 1827); Atlantic horse mackerel *Trachurus trachurus* (Linnaeus, 1758); poor cod *Trisopterus minutus* (Linnaeus, 1758) and John Dory *Zeus faber* (Linnaeus, 1758) and five demersal species (red gurnard *Aspitrigla cuculus* (Linnaeus, 1758); Dragonet *Callionymus lyra* (Linnaeus, 1758); redband fish *Cepola macrophthalma* (Linnaeus, 1758); solenette *Buglossisium luteum* (Risso 1810) and thickback sole *Microchirus variegates* (Donovan 1808)). These were selected based on data from previous trawls at the L4 station and the likelihood that sufficient numbers (>25 individuals per species) would be obtained for analysis. Nomenclature of species follows Froese and Pauly (2011). On each of the trawling dates two trawls were carried out and fish were pooled into one sample for that day. Individuals ranged in size from juvenile to adult. As the number of individuals of each species were not under our control this gave rise to the different numbers of individuals per species.

Fish were frozen within 2 h of capture, and subsequently thawed out at room temperature prior to examination. For each fish, basic measurements were recorded including length, from mouth to central point of caudal fin (mm), body weight (g) and girth, the maximum distance between dorsal and ventral sides (mm). Gastrointestinal tracts were removed by dissection from each fish, from the top of the oesophagus and cut away at the vent.

To prevent contamination, work surfaces were thoroughly cleaned with alcohol, and hands and forearms were scrubbed. Gloves (nitrile) were worn throughout the dissection and manipulation instruments cleaned after every specimen. To minimise the risk of contamination, fish were opened with a scalpel and digestive tracts were immediately placed in plastic zip lock bags and stored for up to 3 h before transferring to clean petri dishes for inspection with a dissecting microscope. All instruments and equipment were checked under microscopes for contamination before use. The digestive tracts were cut open in a similar method to previous studies (Boerger et al., 2010; Davison and Asch, 2011). Each digestive tract was observed for 10 min, any ingested items not resembling natural prey were removed using forceps, transferred to filter paper and sealed in a clean petri dish prior to further analysis. The items were photographed and described according to maximum length, colour, and shape (fragment, fibre, bead, film).

FT-IR was used to confirm the identity of each item removed from the gastrointestinal tract. This was done using a Bruker IFS 66 Spectrometer with a Bruker Hyperion 1000 microscope. FT-IR determines the structure of molecules through analysis of their absorption spectra. To allow for maximum absorbance, specimens were squashed to minimise thickness using a diamond compression cell. Following background scans, 32 sample scans were performed. OPUS v5.5 software then produced output spectra that could be compared to spectra in the OPUS polymer database using Euclidian Distance (ED). This produces a hit quality of the spectral distance between the known spectra and that from the debris being identified, zero being an absolute match and two being no match (i.e. the smaller the number, the closer the match to the reference spectra). Following each sample the microscope slide was wiped with alcohol before subsequent samples were examined.

Samples which produced unclear spectra were manipulated using OPUS software to allow for a clearer comparison to reference spectra. Manipulations included smoothing and baseline corrections. Fragments with a high level of certainty (>70% ED match