Written evidence submitted by Professor Prof. Richard C. Thompson (WQ17)

Marine debris, and in particular plastic debris, is fragmenting in the environment. Much of the debris collected during survey trawls consists of tiny particles or "microplastic" (Law et al. 2010; Thompson et al. 2004). This material was first described by Thompson et al. in 2004 (Figure 1) who identified microscopic fragments on shorelines and in the water column. The definition has since been refined by NOAA in the USA to include pieces or fragments less than 5 mm in diameter (Arthur et al. 2009). The abundance of microplastics is increasing in the oceans (Goldstein et al. 2012; Thompson et al. 2009a). A horizon scan of global conservation issues identified microplastic as one of the top global emerging issues (Sutherland et al. 2010) and a recent review for the Convention on Biological Diversity has shown that around 10% of all reported encounters between marine debris and marine organisms are with microplastics (GEF 2012) .

Figure 1: A) Marine debris on a strandline where it fragments into smaller pieces. B) A fragment of microplastics next to a grain of sand found on a beach in Cornwall, UK. C) Scanning electron microscope image of microplastic fragments. Source: R.C. Thompson.

Microplastic is formed by the physical, chemical and biological fragmentation of larger items, or from the direct release of small pieces of plastic. This includes, for example, industrial spillage of pre-production pellets and powders, microscopic plastic particles that are used as abrasive scrubbers in domestic cleaning products (Fendall & Sewell 2009; Gouin et al. 2011) and industrial cleaning applications such as shot blasting of ships and aircraft (Barnes et al. 2009). Plastic items fragment in

the environment because of exposure to UV light and abrasion, such that smaller and smaller particles form. Some plastics are even designed to fragment into small particles, but the resulting material does not necessarily biodegrade (Roy et al. 2011). Microplastics are known to have accumulated in the water column, on coastal and estuarine shorelines and in subtidal sediments worldwide (Andrady 2011; Barnes et al. 2009; Thompson et al. 2004; Zarfl et al. 2011). However there is limited information on their abundance in freshwater habitats including lakes and rivers or from the terrestrial environment (Rillig 2012).

Microplastics have a relatively large surface area to volume ratio and are therefore have greater capacity to facilitate the transport of contaminants. Fragments as small as 2 μm have been identified from marine habitats (Ng & Obbard 2006), but due to limitations in analytical methods, the abundance of smaller fragments is unknown. As a consequence of the fragmentation of larger items and the direct release of small particles, the quantity of fragments is expected to increase in the seas and oceans (Andrady 2011; Thompson et al, 2009). It is therefore recognised that there are important questions that should be investigated regarding the emissions, transport and fate, physical effects, and chemical effects of microplastics (Zarfl et al., 2011).

Due to their small size moicroplastics have the potential to be ingested by a diverse range of organisms. Laboratory experiments have shown they are readily ingested by filter feeders, deposit feeding worms and detritivores (Thompson et al. 2004). Work with the common mussel (*Mytilus edulis*) has shown that after a single pulse exposure ingested microplastics can be retained for periods in excess of 48 days (Browne et al. 2008). Microplastics have also been reported in natural populations of commercially important crustaceans (Murray & Cowie 2011) and fish (Lusher et al. 2012) as well as in sea birds (van Franeker et al. 2011). It has been suggested that ingestion could lead to direct physical harm and may also facilitate the transport of chemicals to organisms.

Plastics contain a variety of potentially toxic chemicals incorporated during manufacture (monomers and oligomers, bisphenol-A (BPA), phthalate plasticisers, flame retardants and antimicrobials) (Lithner et al. 2011), which can be released into the environment. These chemicals can be transferred to humans through, for example, plastic containers used for food and drink, plastic used in medical applications, and plastic toys (Koch & Calafat 2009; Lang et al. 2008; Meeker et al. 2009; Talsness et al. 2009). Hence, a hazard could exist if plastic fragments containing these chemicals are ingested by marine organisms (Oehlmann et al. 2009; Teuten et al. 2009). Research has shown that chemicals used in plastics, such as phthalates and flame retardants are present in fish, mammals, and molluscs, raising concerns about subsequent toxic effects (STAP 2011). There is limited evidence to confirm a direct link between the chemical characteristics of marine debris and adverse effects on marine life (Besseling et al. 2013). However, experimental studies have shown that phthalates and BPA affect reproduction in all study species, impairing development in crustaceans and amphibians, and generally inducing genetic aberrations (Oehlmann et al. 2009). If these impacts were identified in the natural environment it would pose a substantial problem, as no option exists for remediation due to the nature of the accumulation of debris within the marine environment (GESAMP 2010; Thompson et al. 2009b). It is therefore concerning that concentrations of these substances in the marine environment have been found to match those identified as harmful in laboratory studies, inferring that they could be impacting natural populations (Oehlmann et al. 2009).

In addition to the potential for release of additive chemicals, plastic debris can adsorb persistent, bioaccumulative and toxic substances, including persistent organic pollutants (POPs) that are present in the oceans from other sources. Within a few weeks these substances can become orders of magnitude more concentrated on the surface of plastic debris than in the surrounding water column

(Hirai et al. 2011; Mato et al. 2001; Rios et al. 2010; Teuten et al. 2009). This presents a second mechanism that may facilitate the transport of chemicals to biota upon ingestion. Laboratory studies have shown that very small quantities of plastic (ppm) have the potential to increase the transport of sorbed contaminants to marine organisms. However the role of plastics as a vector is context dependant and is influenced by the availability of other particulates, in particular carbon. The potential for chemical transport varies according to the polymer type (e.g. PE >> PP > PVC) (Teuten et al. 2007). However, the influence of the surrounding physical environment for example the effect of temperature, salinity and competition with other particulates is not clear (Bakir et al. 2012). Hence our understanding of the extent to which plastic particles facilitate the transport of contaminants in the natural environment is uncertain, and more work is required to establish the relative importance compared to other pathways.

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