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Trophic transfer of microplastics does not affect fish personality

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Microplastics are ubiquitous in the marine environment. Their small size makes them bioavailable to a range of organisms and studies have reported ingestion across the food chain. Few studies have demonstrated physical transfer of microplastics between organisms, and no research has assessed the ecological impacts of transferred microplastics and contaminants over different trophic levels. Contaminants associated with plastics can alter animal behaviour; thus, exploring changes in behaviour may be fundamental in understanding ecosystem effects of microplastics. This study explored the effects of microplastics and associated contaminants through the food chain in the marine intertidal zone. We exposed beach hoppers, *Platorchestia smithi*, to environmentally relevant concentrations of microplastics and then fed them to Krefft's frillgobies, *Bathygobius krefftii*, ray-finned fish that inhabit shallow coastal ecosystems. We tested fish personality to see whether there were any changes that could be attributed to trophic transfer of microplastics, as even subtle changes in behaviour can have cascading effects on other organisms and the wider ecosystem. Exploring behavioural changes in response to contaminant exposure is a developing area in ecotoxicology due to its increased sensitivity compared with the traditional LD50 approach. While gobies readily ingested contaminated beach hoppers, we detected no effect of microplastic trophic transfer on fish personality relative to control groups. While chronic exposure studies assessing a suite of behaviours are required, it is possible that the transfer of microplastics via trophic interactions does not provide an additional exposure pathway for contaminants through the food web.

Food webs and trophic interactions are essential for the transfer of energy and nutrients throughout ecosystems. Urbanization, development and industry have influenced pollutants in aquatic systems, with chemicals, metals, pesticides and pharmaceuticals all presenting risks to ecosystems and associated biota (von Glasow et al., 2013; Islam & Tanaka, 2004). Contaminants can accumulate and concentrate in biota (bioaccumulation) and then subsequently transfer through the food web (Borgå, Fisk, Hoekstra, & Muir, 2004; Nfon, Cousins, & Broman, 2008). These pollutants can impact animal physiology (Hontela, 1998) and can also alter behaviours important for foraging, reproduction, social interactions and antipredator behaviour (Clotfelter, Bell, & Levering, 2004; Söffker & Tyler, 2012).

Plastic is a contemporary pollutant in our marine environment. While the deleterious effects of large plastic debris on marine life have received much publicity (Barnes, Galgani, Thompson, & Barlaz, 2009), microplastics are of increasing concern (Cole, Lindeque, Halsband, & Galloway, 2011). Their small size and variable densities mean they occur throughout marine (Law & Thompson, 2014) and freshwater (Eerkes-Medrano, Thompson, & Aldridge, 2015) environments and are bioavailable to a broad range of organisms (Thompson et al., 2004). Microplastics present a physical and chemical risk to organisms. (Rochman, 2013). Potentially toxic additives such as phthalates, bisphenol A (BPA) and flame-retardants are added to many plastics at manufacture to increase functionality and extend their life (Browne, Galloway, & Thompson, 2008; Rochman, 2013). Furthermore, plastics are porous and accumulate and concentrate contaminants including polychlorinated biphenyls (PCBs), pesticides and fertilizers at high intensities from the surrounding sea water (Mato et al., 2001). Many of the additives and the absorbed contaminants are known endocrine disruptors, carcinogens and mutagens (Lithner, Damberg, Dave, & Larsson, 2009) and it is thought that contaminants may transfer from plastics to organisms following ingestion (Teuten, Rowland, Galloway, & Thompson, 2007; Teuten et al., 2009).

Many of the contaminants associated with plastics such as BPA and PCBs can affect foraging efficiency, alter schooling behaviour or

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increase agonistic encounters in fish (Clotfelter et al., 2004; Sloman & Wilson, 2006). Complex behaviours such as foraging, predator avoidance and social interactions are all fundamental to individual fitness and an animal's functioning in an ecosystem (Wolf & Weissing, 2012). Changes in behaviour may take effect even with small quantities of pollutants (Bae & Park, 2014), and while changes in animal health may not be apparent, these behavioural alterations may affect how the animal performs in an ecological context (Scott & Sloman, 2004). Behavioural responses provide useful markers of pollution effects on individuals, potentially performing as reliable and economical indicators of sublethal effects of pollutants (Weis, 2014). Accordingly, there is growing emphasis in ecotoxicology on examining changes in behaviour in response to exposure to contaminants (Oulton, Taylor, Hose, & Brown, 2014).

Microplastics can be ingested by organisms across the marine environment (Fig. 1). A range of studies have assessed effects of plastic consumption at the individual organism level but few have assessed the capacity for microplastics and associated contaminants to move through the food chain. Our understanding of how pollutants can bioaccumulate (Borgå et al., 2004) suggest microplastics provide an additional exposure pathway for contaminants to transfer through the food web. The physical transfer of microplastic fragments between organisms has been demonstrated from mussels, *Mytilus edulis*, to crabs, *Carcinus maenas* (Farrell & Nelson, 2013) and mesozooplankton to macrozooplankton (Setälä, Fleming-Lehtinen, & Lehtiniemi, 2014; Fig. 1). Recently, the transfer of microplastic fragments as well as contaminants was demonstrated in an artificial food chain from *Artemia* nauplii to the intestinal tract of laboratory-raised zebrafish, *Danio rerio*. The study used high concentrations of microplastics spiked with large amounts of benzo(a)pyrene (BaP) and there was no assessment of biological consequences for either *Artemia* or fish (Batel, Linti, Scherer, Erdinger, & Braunbeck, 2016). No studies have assessed the biological effects of a microplastic-contaminated diet on higher trophic levels in an ecologically relevant setting. Exposing animals to more environmentally relevant concentrations and evaluating behaviours in relation to an animal's habitat is important in providing realistic insights to the risks our marine ecosystems face.

We established a model food web to assess the effects of contaminated microplastics via trophic transfer. As microplastics accumulate on shorelines (Setälä, Norkko, & Lehtiniemi, 2016), coastal biota are exposed to them. Coastal ecosystems are often dominated by small crustaceans such as talitrid amphipods. In this study, coastal talitrids (beach hoppers, *Platorchestia smithi*), primary consumers that inhabit the sediment, were exposed to environmentally relevant concentrations of naturally contaminated microplastics and then fed to Krefft's frillgobies, *Bathygobius krefftii*, teleost fish that inhabit shallow coastal ecosystems. Beach hoppers

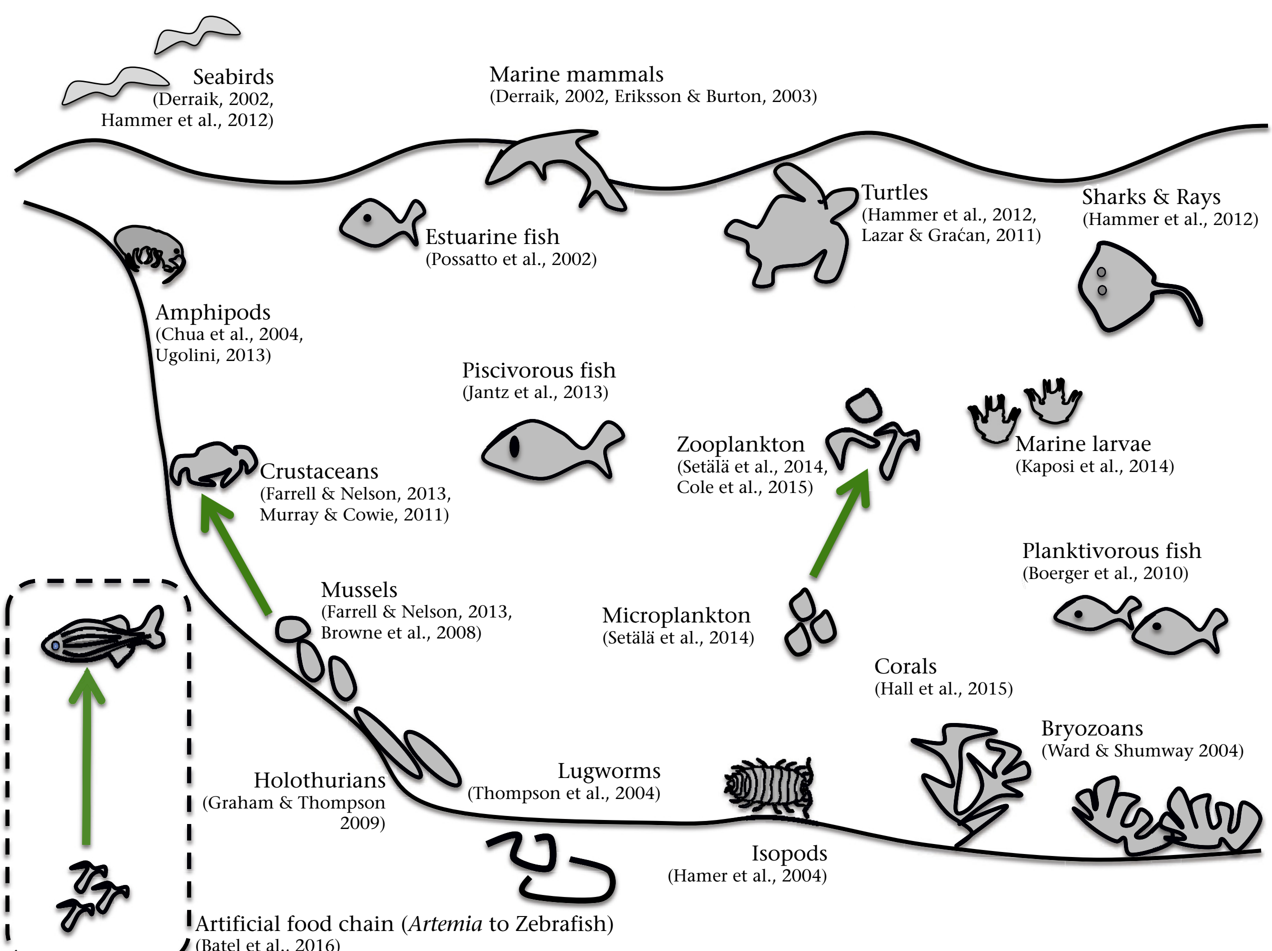

Figure 1. The range of marine biota that have been shown to ingest microplastics. The green arrows indicate where physical transfer of microplastic fragments has been demonstrated. The box in the dotted lines illustrates a recent study where transfer of microplastics and associated contaminants was demonstrated via BaP spiked microplastics in an artificial food chain study Hall et al. 2015.