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Notes

First evidence of microplastics in the African Great Lakes: Recovery from Lake Victoria Nile perch and Nile tilapia

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ABSTRACT

Microplastic contamination in the African Great Lakes is currently unreported, and compared to other regions of the world little is known about the occurrence of microplastics in African waters and their fauna. The present study was conducted in the Mwanza region of Tanzania, located on the southern shore of Lake Victoria. The gastrointestinal tracts of locally fished Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) were examined for plastics. Plastics were confirmed in 20% of fish from each species by Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy. A variety of polymer types were identified with likely sources being urban waste and consumer use. Although further research is required to fully assess the impact of plastic pollution in this region, our study is the first to report the presence of microplastics in Africa's Great Lakes and within the fish species that inhabit them.

Introduction

The presence of microplastics (<5 mm in size) has been extensively reported in the marine environment (see reviews by Derraik, 2002 and Cole et al., 2011), but there is now an increasing focus on documenting microplastic pollution in freshwaters. Plastic pollution in the Laurentian Great Lakes of North America has been well studied (Driedger et al., 2015; Eriksen et al., 2013; Zbyszewski and Corcoran, 2011; Zbyszewski et al., 2014), and other freshwater habitats have also been the subject to investigation, e.g. Lake Hovsgol in Mongolia (Free et al., 2014), Lake Garda in Italy (Imhof et al., 2013) and the River Thames in the United Kingdom (Morritt et al., 2014). These studies not only show that microplastics are present in the freshwater environment, but also relate the type of plastics found to their likely source (urban waste and consumer use). In the absence of environmental sampling, analysis of the gut contents of resident fish populations has also been used to assess the extent of plastic pollution. Lusher et al. (2013) found that plastics are being readily consumed by 10 species, both pelagic and demersal, in the English Channel, and Sanchez et al. (2014) similarly reported, for the first time, that freshwater wild gudgeons, *Gobio gobio*, inhabiting French rivers are also ingesting microplastic debris. With increased monitoring in both marine and freshwater environments and fauna, microplastic pollution can be described as an issue of global concern, but information regarding the presence of plastics in some regions remains scarce. Only a handful of studies exist regarding the extent of plastic pollution in African waters. Both Ryan (1988) and Madzena and Lasiak (1997) characterized plastic litter along the South African coastline, but to date there is no information on plastic pollution in Africa's Great Lakes and the fish that inhabit them. Here, we present data showing the presence of microplastics in the gastrointestinal tracts of Lake Victoria Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*), that begins to fill this knowledge gap.

The present study was conducted in the Mwanza region of Tanzania, located on the Southern shore of Lake Victoria (Fig. 1). Lake Victoria is the world's largest tropical lake (surface area: 68,800 km^2, average depth: 40 m, maximum depth: 84 m, Taabu-Munyaho et al., 2013) and second largest freshwater lake overall (by surface area, the largest being Lake Superior in North America). Land surrounding the lake is amongst the most densely populated in the world, and this population growth is set to continue — by the year 2020 an estimated 53 million people will inhabit the area around Lake Victoria (Canter and Ndegwa, 2002). The majority of economic activities in the region are associated with the lake with one of the most important being fishing. The two species used in the present study, Nile perch and Nile tilapia, are

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Fig. 1. The map of study area showing the Mwanza region (A). The local fishing area extends across the Mwanza Gulf and to Ukerewe Island. Inset Lake Victoria (LV) bordered by Uganda, Kenya and Tanzania. The Mwanza region located on the southern shore of Lake Victoria is highlighted. (B) Urban waste in Mwanza, including plastic debris, collects in drainage ditches which are a potential source of plastic pollution in Lake Victoria. (C) Nile tilapia (photographed prior to dissection) and Nile perch used in this study were purchased from the market at Mwanza.

economically and ecologically important. Both species were introduced to Lake Victoria in the 1950s and 1960s with the aim of supplementing native fish populations that had declined due, in part, to over fishing (Ogutu-Ohwayo, 1990; Taabu-Munyaho et al., 2013). However, this introduction was detrimental to the native species (Kishe-Machumu et al., 2015), particularly the native tilapiine species such as the Victoria tilapia (*Oreochromis variabilis*) and singidia tilapia (*Oreochromis esculentus*), which subsequently disappeared from parts of the Lake (Njiru et al., 2004; Ogutu-Ohwayo, 1990). Thus Nile perch and Nile tilapia are established as dominant commercial and ecological species, and therefore represent logical choices by which to monitor microplastic pollution in the area. Moreover, their differing feeding habits may provide additional information by which to contextualize plastic ingestion. Nile perch are predatory fish feeding on small fish and macroinvertebrates, whereas Nile tilapia are omnivorous with a diet ranging from plankton to small fish.

Methods

In March 2015, 20 Nile perch and 20 Nile tilapia were purchased from Mwanza harbor market, where fish are caught and sold daily. The fishing territory for both species extends to Ukerewe Island (the largest island in Lake Victoria) to the north of Mwanza and across the Mwanza Gulf to the neighboring district of Sengerema (Fig. 1). Nile perch and Nile tilapia were 46–50 cm and 25–30 cm in length, and 500–800 g and 500–700 g in weight, respectively. For each fish, the dissection of the entire gastrointestinal tract (buccal cavity to anus) was conducted on site. All efforts were made to eliminate sample contamination with separate clean dishes used for each fish and thorough cleaning of dissection utensils between samples. A preliminary examination was made of each gastrointestinal tract and in the case of Nile perch undigested gastropods and cichlids were removed. Gastrointestinal tracts and their contents were then individually preserved in 96% ethanol and transported to laboratory facilities at the University of Dar es Salaam (Dar es Salaam, Tanzania). In the laboratory, NaOH digestion (10 M NaOH at 60 °C for 24 h) was used to isolate plastic litter from the organic tissue. The NaOH method has been shown to digest organic matter with an efficacy of >90% (Cole et al., 2014) and our tests of this protocol prior to its use confirm such high efficiencies (96.6 $\pm$ 0.9%, n = 5, data not shown). Importantly, NaOH digestion has a minimal impact on the chemical and physical states of plastics, especially when compared to strong acid digestion which, whilst also being an effective digestant of organic matter, can discolor or degrade plastics. Post-digestion, plastics and a minimal amount of partially digested tissue were rinsed from the NaOH through 250 μm mesh stainless steel sieves under running water and placed on filter paper to dry. Samples were then brought to the laboratory at Roskilde University (Denmark) and suspected plastic pieces were separated from other digested residue under light dissection microscope.

The chemical composition of all suspected plastics were identified non-destructively by Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy (conducted at the National Museum of Denmark), a standard analytical technique for identifying the chemical composition of samples larger than 0.5 mm. Scans were run at a resolution of 2 cm^{-1} between 4000 and 650 cm^{-1} on a Bruker Alpha FT-IR instrument (Bruker, Billirica, MA, USA) fitted with a diamond internal reflectance element. Spectra were compared with standard references on the same instrument and processed using Opus software supplied by Bruker.

Results

Suspected plastics were recovered from the gastrointestinal tracts of 11 perch (55%) and 7 tilapia (35%). However, some plastics were too small (i.e. <0.5 mm) to have their chemical structure confirmed by ATR-FTIR. In addition, spectroscopy of some suspected plastic samples showed that their compositions most closely resembled cellulose, suggesting these samples were likely plant material or paper originating from perhaps newspaper, tissues or cigarette filters. Thus 20% of each fish species (i.e. 4 individuals) contained confirmed microplastics within their gastrointestinal tracts. The polymers recovered from the fish were: polyethylene, polyurethane, polyester, polyethylene/polypropylene copolymer and silicone rubber (Fig. 2). The common use of such materials includes packaging, clothing, food and drink containers, insulation and industrial applications (Table 1).

Discussion

This work provides the first evidence that microplastics are present in the African Great Lakes and that they are ingested by economically important fish species. In addition to confirming the ingestion of microplastics by freshwater fish species (Sanchez et al., 2014), we identify the chemical composition of microplastics found in Lake Victoria fish. However, ours is a preliminary study and only limited conclusions can be drawn. Plastics were confirmed in only 20% of both species, but due to the constraints of ATR-FTIR analysis and the inability to confirm the identity of the smaller-sized suspected 'microplastics', we likely underestimate the true extent of plastic ingestion by Nile perch and Nile tilapia. Similarly, it is not possible to determine whether the feeding preferences of the two species effected their ingestion of plastics. Thus, whilst our study reports the presence of plastics in these species, further research needs to be undertaken to fully characterize the extent of microplastic pollution in Lake Victoria.

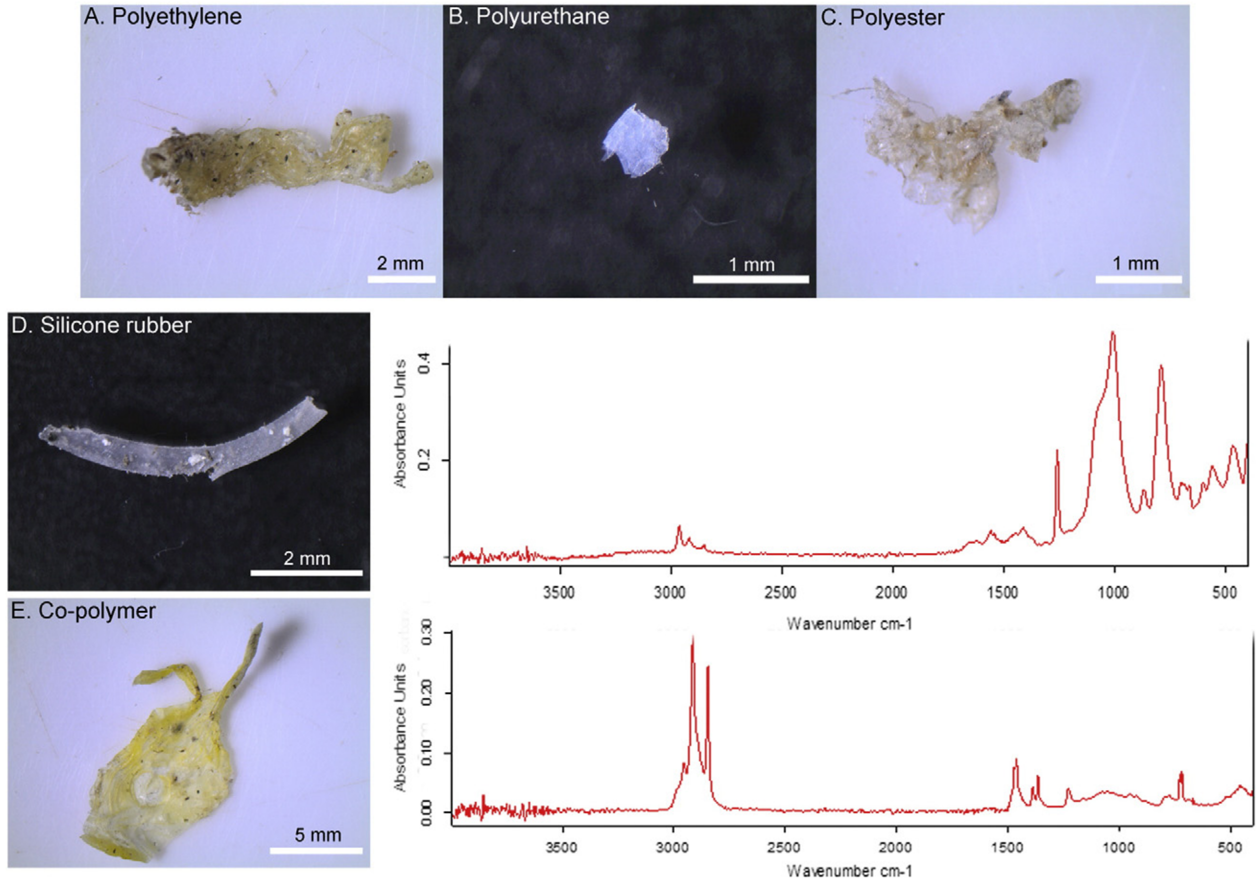

Fig. 2. Variety of plastic debris recovered from Nile perch and Nile tilapia. Images A–E are examples of the range of polymers isolated after NaOH digestion of the gastrointestinal tissue. In each case the identity of the polymer was confirmed by ATR-FTIR spectroscopy. Spectra attributed to silicone rubber (D) and polyethylene/polypropylene co-polymer (E) debris are shown next to their respective plastic samples.

Microplastics ingested by the fish (Fig. 2) may be secondary microplastics which have resulted from the degradation and breakdown of larger plastic pieces (Derraik, 2002). The identification of different polymers allows speculation regarding points of entry of plastics into the study area and a likely source of the input of such materials into the Mwanza Gulf area is from the drainage ditches that are filled with urban waste, including plastic products (Fig. 1B).This may be a particular problem during heavy rain when input into the lake is increased. In common with other studies conducted at freshwater sites (Eriksen et al., 2013; Free et al., 2014), it appears that the nature of the plastic pollution may be related to the usage and waste by the local human population. The characterization of plastic litter found in Mongolia's Lake Hovsgol has led to calls for better waste management (Free et al., 2014), a call we echo for the Mwanza region.

The ingestion of plastics by Nile perch and Nile tilapia may potentially lead to disturbances in their digestive physiology or deleterious effects arising from the possible consumption of chemical pollutants adsorbed to plastic surfaces (i.e. 'vector-effect', Cole et al., 2011; Syberg et al., 2015). Although both organic pollutants (Fries and Zarfl, 2012; Koelmans et al., 2013) and trace metals (Ashton et al., 2010; Holmes et al., 2012) have been shown to adsorb to a variety of plastic surfaces, the vector effect has yet to be unambiguously demonstrated. However, in some studies, and particularly when the adsorption of pollutants to plastic surfaces is promoted, microplastics have been shown to alter pollutant–organism interactions (Chua et al., 2014; Khan et al., 2015). Thus when assessing the effects of microplastics to field populations it may be necessary to consider the other chemical pollutants present in that environment.

Table 1
Polymers recovered from the gastrointestinal tracts of sampled fish, and their common uses and potential source of plastic pollution in Lake Victoria.

Polymer	Common uses and potential sources
Polyethylene/polypropylene co-polymer	Packaging, carrier bags
Polyethylene	Carrier bags, food wrappers, beverage bottles
Polyester	Beverage bottles, textile (clothing, carpets, curtains)
Polyurethane	Insulation, sealants, packaging
Silicone rubber	Industrial sealants. O-rings, molds, food storage

Our study is the first to describe the presence of microplastics in fish inhabiting Africa's Great Lakes. Within Lake Victoria, Nile perch and Nile tilapia are both economically and ecologically important, especially since they are heavily consumed by local human residents. Future investigations should consider the trophic transfer of microplastics through the freshwater food chain, particularly in the case of Nile perch which are known to feed on smaller fish (including haplochromine cichlids) and macroinvertebrates, as well as any potential 'vector effect' that facilitates the movement of adhered contaminants through the food chain. Given the density of the human population in the region and its estimated growth, the prevalence of microplastics in Lake Victoria would be expected to increase. The reliance on the lake as a resource means that any potential impacts of microplastics on the ecosystem and biota need to be researched, assessed and, if possible, mitigated.

Author information

F.J.B and B.S.M are joint first authors of this study and contributed equally to design, sample collection and analysis.

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