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Baseline

Micro-plastic ingestion by waterbirds from contaminated wetlands in South Africa

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ABSTRACT

Despite a large literature on the impacts of micro-plastic pollution in marine ecosystems, very little research has focused on these pollutants in freshwater ecosystems. Recently, however, a few studies have demonstrated that micro-plastic pollutants are ingested by freshwater taxa, including birds. To explore this potential environmental threat in African freshwater systems we quantified micro-plastic pollutants in the faeces and feather brushings of seven southern African duck species. We analysed 283 faecal samples and 408 feather brushings, and found that 5% of faecal samples and 10% of feather samples contained micro-plastic fibres. The presence and abundance of micro-fibres differed between sampling sites, with significantly higher amounts recorded for the site that received effluent from a sewage treatment facility. Additionally, micro-fibre presence differed across duck species, indicating that foraging behaviour affects plastic ingestion. Our study confirms that African freshwater ecosystems and the biodiversity they support are under threat from micro-plastic contamination.

Plastic contamination of the marine environment is a well-known environmental problem (Bergmann et al., 2015). The harmful consequences of plastic pollution on marine fauna, especially through plastic ingestion and entanglement, are well documented (Gregory, 2009; Ryan, 2016). Many plastic contaminants are buoyant and durable, enabling their spread to even the most remote habitats (Eriksen et al., 2014). Of particular concern is the abundance of micro-plastics in the world's oceans (Andrady, 2011), which are defined as particles smaller than 5 mm (Moore, 2008). In addition to physical effects from ingestion, micro-plastic litter absorbs persistent organic pollutants (POPs), and when ingested by marine species present a route through which POPs can enter a food web (Andrady, 2011). Surprisingly, despite demonstrating the detrimental effects of micro-plastics in oceans, little research has focused on freshwater and terrestrial systems where these contaminants pose similar threats to biodiversity (Eerkes-Medrano et al., 2015; Thompson et al., 2009).

Until recently, little was known about the distribution and abundance of micro-plastics in freshwater systems, but they have now been documented in North America, Europe and Asia (reviewed in Eerkes-Medrano et al., 2015) and in one urban river system in Africa (Nel et al., 2018). These micro-plastic contaminants can originate from both primary sources e.g. micro-beads in facial cleansers and plastic resin for commercial use (Eriksen et al., 2013; Gregory, 1996), and secondary sources, through the breakdown of larger plastic items. A common source of secondary micro-plastics are synthetic fibres from washing clothes mainly made of polyester or acrylic, which are then discharged in high concentrations in household effluent (Browne et al., 2007, 2011). There is now good evidence that micro-plastics occur widely in freshwater systems, but their abundance varies widely based on human population densities, proximity to urban centres and the quality of waste-water treatment (Eriksen et al., 2013; Moore et al., 2011). However, the implications of the presence of micro-plastics on fauna in freshwater systems is still little known.

The few studies on freshwater taxa to date suggest that, as in the marine environment, animals across habitats, feeding guilds, and trophic levels ingest micro-plastics. A recent review of freshwater field and laboratory studies demonstrated that at least five species of invertebrates and ten species of fish ingest micro-plastics (Eerkes-Medrano et al., 2015). The amount of plastic ingested varied across study systems and taxonomic groups, and in freshwater fish between 4.9% and 33% of individuals had ingested micro-plastics (Rochman et al., 2013; Sanchez et al., 2014). Among animals most at risk from micro-plastic ingestion are freshwater birds, which may ingest these contaminants directly from the water column while filter feeding or through the ingestion of other organisms. These micro-plastics may remain in the gizzard and have physical effects within the digestive system, or as in marine systems facilitate the bioaccumulation of POPs in freshwater, and potentially terrestrial food webs. Reports on micro-

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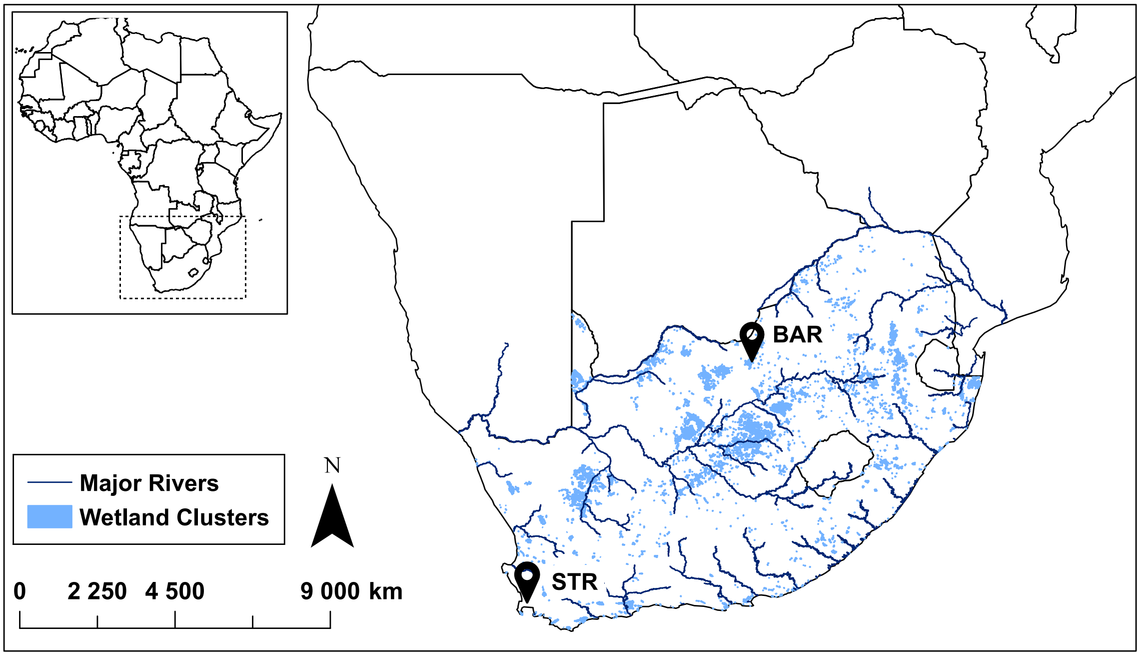

Fig. 1. Location of the two studied wetlands, Barberspan Nature Reserve (BAR) and Strandfontein (STR), in southern Africa (inset). Shaded clusters represent major wetland complexes and dark lines major rivers (stream order > 4) in South Africa.

plastic ingestion by freshwater birds are few and to date, the only records in freshwater ducks are from Europe and North America (English et al., 2015; Faure et al., 2012; Gil-Delgado et al., 2017; Holland et al., 2016).

We report the presence of micro-plastics in freshwater ecosystems in South Africa (Fig. 1), and the ingestion of these micro-plastics by freshwater birds, based on data from ducks. We test for differences in the presence and abundance of micro-plastics in feather brushings and faecal samples collected from ducks at two wetland systems. Our chosen wetland systems, Barberspan Nature Reserve and False Bay Ecology Park (Strandfontein), are both important bird and biodiversity areas (IBAs) and recognised under the Ramsar Convention as supporting globally significant numbers of waterbirds (Marnewick et al., 2015). We predict a higher occurrence and abundance of micro-plastics in samples collected from ducks at Strandfontein, which receives effluent from the Strandfontein Sewage Works that processes waste water from a large proportion of Cape Town's southern suburbs. Additionally, we predict that the presence and abundance of micro-plastics in the faecal samples will vary between duck species because of differences in diet and foraging depth.

Samples were collected from Barberspan Nature Reserve, North West Province (26°35′ S 25°34′ E) in May/June and False Bay Ecology Park, Strandfontein, Western Cape (34°04′ S 18°30′ E) in January/February in 2013 and 2014. These dates correspond with peak wing feather moult by ducks at these sites. Approximately one third of the ducks sampled (predominantly Egyptian Geese *Alopochen aegyptiaca* and Yellow-billed Ducks *Anas undulata*) were undergoing wing feather moult, which renders them flightless for several weeks. As a result, their movement and foraging was confined to the wetlands where the birds were sampled, giving a reliable estimate of micro-plastics prevalence in the immediate environment. The sampling formed part of a larger study investigating the role of ducks in seed and invertebrate dispersal (Reynolds and Cumming, 2015, 2016). Hence, our primary objective was not to sample the waterbodies for micro-plastic contamination and we have used feather brushings as a proxy for micro-plastic presence and abundance in the environment. We acknowledge that while these samples provide a useful comparison between wetland systems, a comprehensive sampling of the waterbodies will provide a better representation of the prevalence of micro-plastics in these environments.

Faecal samples ($n = 283$) were collected from six waterfowl species: Red-billed Teal *Anas erythrorhyncha* ($n = 35$), Cape Shoveler *A. smithii* ($n = 35$), Yellow-billed Duck ($n = 60$), White-faced Duck *Dendrocygna viduata* ($n = 8$), Egyptian Goose ($n = 115$) and Spur-winged Goose *Plectropterus gambensis* ($n = 30$) (Table 1). Fresh faecal samples were collected from monospecific roosting sites, except for Red-billed Teal and White-faced Duck, where samples were collected from captured birds (see Reynolds and Cumming, 2016 for details). Large numbers of ducks were present at the study site and care was taken to collect samples at least 2 m apart so we could be confident that samples represented independent replicates. Faecal samples were collected in individual vials and stored until processing.

Feather brushings ($n = 408$) were collected from live ducks captured in baited funnel traps or mistnets and included samples from Cape Teal *Anas capensis* ($n = 14$), Red-billed Teal ($n = 51$), Yellow-billed Duck ($n = 141$), White-faced Duck ($n = 8$) and Egyptian Goose ($n = 194$) (Table 1). Captured ducks were brushed over a large tray with a fine-toothed comb for three minutes, and then their feet were scrubbed with a toothbrush and rinsed with tap water into the same collection tray. This residue was washed onto filter paper, lightly air-dried and stored in a sealed envelope until processing. This protocol could introduce micro-plastic contaminants. However, since the

Table 1
The percentage of faecal samples (ingested plastic) and feather brushings containing at least one fibre and the corresponding sample size in parentheses.

Duck species	Site	Ingested plastic	Plastic on feathers
Egyptian goose	Barberspan	1% (60)	1% (75)
	Strandfontein	1% (55)	8% (119)
Yellow-billed duck	Barberspan	3% (60)	6% (95)
	Strandfontein	_	17% (46)
Red-billed teal	Barberspan	2% (35)	6% (49)
	Strandfontein	_	50% (2)
Spur-winged goose	Barberspan	3% (30)	_
White-faced duck	Barberspan	0% (8)	0% (8)
Cape shoveler	Strandfontein	17% (35)	_
Cape teal	Strandfontein	14% (14)	_