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Cover image: The mudskipper *Periophthalmus argentilineatus* on the mangrove of Ulo Beach, Cabo Delgado, North Mozambique. © José Paula, 2006

Presence of microplastics in jellyfish (*Crambionella orsini*) along the Kenyan coast

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Abstract
Microplastics are plastic particles less than 5 mm in diameter. These plastics mostly result from degradation of larger plastics. Due to their small size, they are often accidentally ingested by sea faunas, particularly the deposit and filter feeders. However, information on the ingestion of microplastics by sea fauna such as jellyfish is rare. This paper provides evidence of ingestion of microplastics by jelly fishes (*Crambionella orsini*) along the Kenyan Coast. Samples were taken from three stations (Mikindani and Makupa in Mombasa, and Dabaso in Mida Creek) between 31st January 2018 and 3rd February 2018 using tow nets. Samples were digested using 10 % KOH at 60 °C for 24 hrs and sieved through a 38 µm sieve. Products below 38 µm were filtered using a 0.8 µm Whatman filters, then dried in an oven and viewed under a dissecting microscope for microplastics. Suspected microplastics were confirmed using a hot needle test. Microplastics obtained were mainly fibres of different colours: black, blue, green, colourless, purple, red and yellow. Colourless fibres were the majority accounting for 53 % of the total number of fibres while purple fibres were the least at only 1 %. Mean concentration of microplastics was highest in Dabaso (0.05 mp/g of tissue), whereas in Mikindani and Makupa were almost equal (i.e., 0.03 ± 0.003 mp/g in Mikindani, and 0.03 ± 0.01 mp/g in Makupa). Statistically, the means were not significantly different between the stations ($F_{1,2}$ = 1.34; P = 0.43). This study presents evidence of contamination of the Kenyan coastal waters by microplastics and their ingestion by sea fauna such as jellyfish. Results of this study will help reinforce the plastic ban in the country to prevent further accumulation in the environment.

Keywords: microplastics, jelly fish, Kenyan coast, dissecting microscope, whatman filters

Introduction
Study background
This study formed part of a broader study whose aim was to investigate the presence and concentration of microplastics in marine waters along the Kenyan coast. During the sampling for microplastics from the water column, a few jellyfishes were caught by chance in tow nets at the three stations (Mikindani and Makupa in Mombasa, and Dabaso in Mida Creek). The jellyfishes were thus investigated for microplastics. Data obtained from this study will help to increase understanding of the interaction of microplastics with the sea fauna along the Kenyan coast, and especially the zooplankton feeders such as jellyfishes that accidentally ingest the microplastics in the water column. Currently, only a few studies have demonstrated the presence of microplastics in jellyfishes globally.

Introduction
Since the discovery of plastics in the 1950s (GESAMP, 2015), an increase in their production has been witnessed (Dehaut *et al*., 2016). Plastics are used for a variety of purposes including for: packaging, construction of houses, agriculture, clothing, footwear, personal cleaning products and electronics (Boucher and Friot, 2017). This wide application is due to their durability, excellent thermal and electrical insulation as well as their ability to be moulded into various shapes (Dris *et al*., 2015). The most widely used plastics include Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polystyrene (PS) and Polyethylene Terephthalate (PET), representing about 90 % of the world's total production, thus making them the major pollutants in the environment (Ivar do Sul and Costa, 2014).

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Plastics are ubiquitous in both the marine and coastal ecosystems (Dris *et al*., 2015). Of particular concern are the microplastics (<5 mm in diameter), which are classified either as primary or secondary microplastics (EFSA, 2016: Smith *et al*., 2018; Wright *et al*., 2013). Primary microplastics are plastics that are designed to be microscopic, and include materials such as beads, fibres, pellets and resins (EFSA, 2016). Secondary microplastics normally result from fragmentation of larger plastic materials (Milisenda *et al*., 2014).

The small size of microplastics makes them invisible, especially to suspension, deposit and detritic feeders such as oysters and crabs which mistake them for prey (Lusher *et al*., 2017). Ingestion of microplastics has been observed in a number of marine fauna including fishes, echinoderms, crustaceans, cetaceans and bivalves (Jamieson *et al*., 2019). Microplastics taken by organisms at the lower trophic levels, that is, zoo- or phytoplankton, are likely to be incorporated into the food chain (Katija *et al*., 2017). According to Robinson *et al*. (2014), jellyfish inhabit the pelagic environment, hence their diet tends to overlap with those of the forage fish. Mesozooplankton for instance, contribute greatly to the diet of *Aurelia* spp. Other jellyfish species such as *Rhizostoma octopus* are predators, feeding mainly on fish eggs and larvae. Morais *et al*. (2015) observed that jellyfish diet is not only restricted to zooplankton with some species such as *Blackfordia virginica* feeding also on phytoplankton, detritus and ciliates. Such jellyfish, therefore, are likely to ingest microplastics by mistaking them for prey leading to serious effects. On the other hand, jellyfishes act as food for various sea organisms including seabirds, sea turtles, sunfish and juvenile fish (Robinson *et al*., 2014). Ingestion of microplastics by jellyfish, therefore, has implications on the marine food web as well humans as some of the jellyfish predators such as fish are highly valued human food.

The objective of this study was to establish the presence and concentration of microplastics in jellyfish from three sites: Makupa, Dabaso and Mikindani, located along the Kenyan coast. In addition, the shape, length and colours of the plastics were determined.

Materials and methods

Field methods

Sampling was carried out during the spring low tide between 31st of January and 3rd of February 2018. Jellyfish were encountered at all the three stations and were caught by towing 500 μm mesh size nets for approximately 10 minutes. Samples were stored in cooler boxes to be transported to the laboratory for further analysis.

Laboratory methods

Jellyfish were weighed using a weighing balance and the weights recorded. Samples were then rinsed in distilled water to remove any microplastics attached on the surface. Replicates of each sample were put in separate beakers in which 10 % KOH was added until the sample was completely submerged, and then incubated at 60 °C for 24 hrs. After digestion, samples were sieved using a 38 μm sieve and filtered through filter membranes (0.8 μ Whatman filters). The membranes were dried in an oven for 12 hrs and viewed under a dissecting microscope. Possible microplastics were isolated into a glass petri dish and confirmed using a hot needle. Materials that were plastics melted at the point of contact with the hot needle. The shape, colour, and length of the plastics were determined. There was, however, no attempt to identify the types of plastics owing to their microscopic size.

Quality control

Contamination of the samples was minimized by working in a laboratory with minimum movement, wearing a cotton lab coat, using glass equipment,

Table 1. Mean (± SE) lengths (mm) of microplastics of different colours in jellyfish at different stations along the Kenyan coast.

	Black	Blue	colourless	Green	Red	Purple	Yellow	*F*	*p*
Dabaso	1.31	3.00	1.50	0.00	2.50	0.00	0.00		
Makupa	0.79 ± 0.79^{aA}	2.34 ± 2.34^{Aa}	3.21 ± 0.71^{aA}	0.94 ± 0.93^{aA}	2.34 ± 2.34^{aA}	0.75 ± 0.74^{Aa}	-	0.83	0.59
Mikindani	3.24 ± 3.24^{aA}	1.5 ± 1.49^{Aa}	1.62 ± 0.03^{aA}	0.37 ± 0.37^{aA}	0.94 ± 0.94^{aA}	-	1.5 ± 1.49^{aA}	0.58	0.76
$F_{2,2}$	0.29	0.11	3.17	0.33	0.2	0.6	0.6		
P-Value	0.78	0.9	0.24	0.76	0.83	0.63	0.63		

Means ($\bar{x} \pm SE$) within columns followed by the same lowercase letters are not significantly different; means ($\bar{x} \pm SE$) along rows followed by the same uppercase letters are not significantly different (Tukey pairwise comparisons of means $p \leq 0.05$).

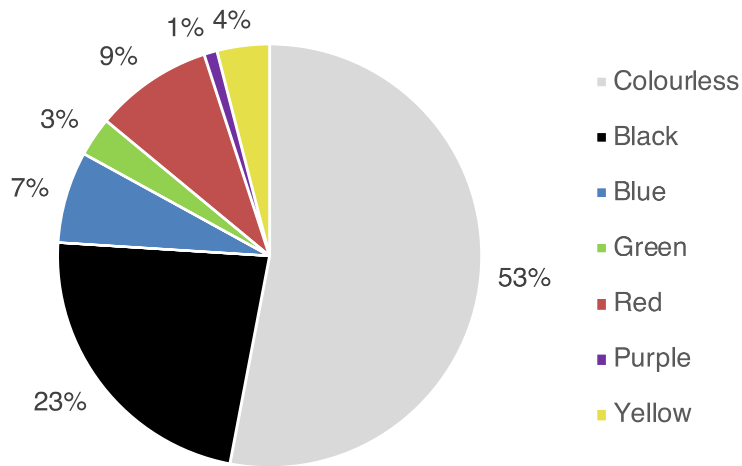

Figure 1. Proportion of microplastics of different colours ingested by jellyfish

using distilled water, and rinsing all the equipment with distilled water before use. A control was set up on the working table using a membrane filter. The filter was observed under a dissecting microscope and no microplastics were found, therefore it was assumed that the study was at minimum risk of plastic contamination.

Data analysis methods

Data analysis was performed using the Rcmdr package in R-console. One-Way ANOVA was used to compare the mean concentration, length and colours of microplastics in jellyfish sampled from different stations. Where means were significantly different, the Tukey's post-hoc test was used to check the differences ($p < 0.05$).

Results

Jellyfish distribution

A total of 9 jellyfish were obtained for the study, with Makupa having the highest number (n = 5). Dabaso and Mikindani had a total of 2 jellyfish each. The jellyfish belonged to the genus *Crambionella* sp. Weights of individual jellyfishes ranged between 200 g and 1000 g. Jellyfish from Mikindani were heavier (890 g – 1000 g) than those from Dabaso and Makupa, and were therefore considered as separate samples, whereas the small-sized jellyfish were grouped together to form a sample.

Microplastic occurrence in jellyfish samples

Microplastics obtained from the jellyfishes were mainly fibres of seven different colours (black, blue, green, colourless, purple, red and yellow (Fig 1). Colourless fibres were the most dominant fibres accounting for 53 % of the total number of fibres, whereas purple fibres were the least at 1 % (Fig. 1). The length of the fibres ranged between 0.3 mm – 3 mm (Table 1). Colourless fibres had a relatively longer mean (±SE) length (2.23 ± 0.46 mm) than the other fibres, whereas purple fibres were the shortest with a mean of 0.30 ± 0.30 mm. Variations in these lengths were however

Table 2. Mean weights of jellyfish and their corresponding microplastic (mp) concentration (mp/g tissue).

Station/replicate	Mean Weight (g)	Mp Conc (mp/g tissue)
Mikindani A	890	0.028
Mikindani B	1000	0.022
Makupa A	897	0.041
Makupa B	831	0.012
Dabaso A	298	0.05

not significant ($F_{6, 28}$ = 1.3; p = 0.29). Mean concentration of microplastics in jellyfish was determined in terms of the number of microplastics per gram of their tissue (mp/g tissue). Mean concentrations were 0.05 mp/g tissue in Dabaso, 0.03 ± 0.01 mp/g tissue in Makupa, and 0.03 ± 0.003 mp/g tissue in Mikindani (Table 2). The mean concentrations of microplastics between the sites were not statistically significant ($F_{1, 2}$ = 1.34; p = 0.4).

Discussion

This study has established the presence of microplastics in jellyfish on the Kenyan coast, particularly along the creeks where most subsistence fisheries occur. Results of this study represent the second evidence of microplastic ingestion by jellyfish, with the first evidence being reported by Macali *et al*. (2018) on *Pelagia noctiluca*. Jellyfish play an integral role in the marine food web as either predators or prey. They trap their prey by the use of tentacles, and are therefore likely to ingest plastic particles in the process (Mandal and Gosh, 2010). Ingested microplastics may be passed on to their predatory fish including bogue (*Boops boops*), chum salmon (*Oncorhynchus keta*), and filefish (*Stephanolepis cirrhifer*), which are commercially valuable (Milisenda *et al*., 2014). Eventually, microplastics in the fish tissues may end up in human diets and lead to health complications.

Sites for this study were chosen based on their susceptibility to plastic waste pollution. For instance, Makupa creek is located next to the Kibarani dumpsite, and hence there is potential leakage of nutrients from the dumpsite into the creek which favours phytoplankton growth and abundance of zooplankton that are eaten by jellyfish (Purcell *et al*., 2007). This explains the high number of jellyfish in Makupa compared to Dabaso and Mikindani.

Microplastics obtained from the jellyfish samples were classified according to their shape, colour and length. These microplastics were mainly fibres and as reported in other studies, ingested fibres may have come from urban surface runoff, fisheries, wastewater treatment plants, shipyards, rivers, synthetic textiles, and personal care products (Graca *et al*., 2017). The microplastics were of different lengths and colours. Variation in the colour of microplastics is an indication that they were from multiple sources. Of all the colours, colourless fibres were dominant suggesting that the sea was highly contaminated by these types of plastics.

It was further noted that the concentration of microplastics among the stations was not statistically different. In fact, the concentration in Dabaso, which is a nature reserve, was higher than Makupa and Mikindani. This reveals the trans-boundary nature of plastic pollution to the extent that even protected areas are not exempted. This study reveals the contamination of Kenyan coastal waters by microplastics and their ingestion by sea fauna such as jellyfish which mistake them for food. Results of this study will help policy makers to make informed decisions regarding plastic waste pollution so as to prevent their future accumulation in the environment.

Conclusion

This study has established ingestion of microplastics by jellyfish along the Kenyan coast and especially within the creeks where most subsistence fisheries occur. This suggests the contamination of these environments by microplastics. Microplastics obtained from the study were mainly fibres that were of different colours suggesting that the plastics came from multiple sources. Colourless fibres were the dominant fibres indicating high contamination of the ocean with these types of fibres. This study reinforces the need for the plastic bag ban policy in the country and recommends proper plastic waste management strategies to reduce their accumulation in the environment.

Recommendation

This study recommends further investigations to establish which body parts of the jellyfish accumulated these microplastics and what polymers constituted the microplastics to enable prediction of the possible sources of microplastics entering the ocean. Further research should also be conducted to establish the concentration of microplastics in the water column that these organisms inhabit.

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