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# Microplastics in Mussels Along the Coast of Cape Town, South Africa

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## Abstract

Microplastic (MP) contamination in marine organisms is a growing field of research internationally. However not much is known about MP presence in invertebrates in southern Africa. The aim of this study was to determine whether MPs occurs in mussels prevalent in Cape Town, South Africa. Mussels (*Mytilus galloprovincialis*, *Choromytilus meridionalis* and *Aulacomya ater*) were sampled at 27 sites in October 2018 and MPs were recorded in 98% of mussels analysed. Most MPs were filaments, dark in colour and the size ranged between 50 and 1000 µm. There were no significant differences in MPs between the mussel species, with an average of 2.33 (standard error ± 0.2) MP particles/g and 4.27 (standard error ± 0.5) particles/individual being recorded for all sites combined. This is the first record of MPs in mussels in the region and provides a baseline for further investigations and monitoring of MPs.


**Keywords** Microplastics · Mussels · Filter-feeders · Cape town

The increased lack of sound waste management is well-known throughout the world (Silpa et al. 2018). Poor management of waste has resulted in an increase in degradation of the environment, increasing the problem of pollution to the extent that the effects on ecosystems seems irreversible. Included in waste and litter pollution are plastics that are released into the environment and eventually end up, and accumulate in, coastal oceanic waters (Law and Thompson 2014). More than 240 million tons of plastic was produced globally in 2004 (Thompson et al. 2004) and this has increased to 348 million tons in 2017 (Plastics Europe 2018). Most plastics are produced as single-use items (Barrows et al. 2018) and once discarded, eventually end up in coastal areas and the open ocean (Thompson et al. 2004). Plastic eventually breaks up into smaller pieces, known as microplastics (MPs) (particles less than 5 mm in diameter) and have become a dominant component of marine plastic litter (Law and Thompson 2014).

Microplastics have been found in almost every marine ecosystem on earth, from the open oceans (Law and Thompson 2014;), ocean depths (Jamieson et al. 2019), coastal areas (Setälä et al. 2016) and estuarine systems (Naidoo et al. 2015). Given the ubiquitous distribution of MPs, they pose environmental risks due to their availability (Wright et al. 2013) and are ingested by most marine organisms, including shellfish such as mussels (Li et al. 2015; Renzi et al. 2018; Woods et al. 2018). Ingested MPs are also potential sources of harmful contaminants such as organic pollutants and metals (Digka et al. 2018) which have the potential to bioconcentrate up the food chain and pose risks for human health (Wright et al. 2013). Filter-feeders such as mussels are susceptible to MP ingestion as they are non-selective regarding particle filtration and ingestion is size-dependant (Moore et al. 2001). Mussels are considered ideal organisms to monitor MPs (Li et al. 2016) and given their ubiquitous distribution in South Africa (Branch et al. 2010), can be considered as a monitoring tool for MPs in the region.

South Africa produced 42 million tonnes of waste in 2017, of which an estimated 11% was recycled (DEA 2018). Of this waste generated in South Africa, an estimated 2.2 million tonnes was plastic (5% of total waste generated), of which 15% was recycled and the remaining 1.9 million tonnes ending up in landfill sites (DEA 2018). It is estimated that the Western Cape Province, in the south western part of South Africa, contributes 20% of the total waste produced in South Africa which amounted to 8.4 million tonnes of general waste and 0.4 million tonnes of plastic produced in 2017 (DEA 2018). Cape Town comprises 64% of the

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total population of the Western Cape (StatsSA 2018) and as the major metropole in the province, can be considered the major contributor to general and plastic waste generated in the province. A major contributor to MP fibres in coastal areas is wastewater treatment plants WWTPs (Li et al. 2016, 2018). The Western Cape has the highest number of WWTPs (158) per province in South Africa and has the second highest daily inflow in the country (908 million L/day) (DEA 2018).

Records of MPs in coastal areas of SA is a relatively new field, with very limited research published. Ryan (1988) analysed plastics in the sea surface waters off the south west coast of the Western Cape and recorded an average of 3.64 plastic (mainly foam fragments) particles/m$^2$. More recent studies in South Africa investigated MPs in sandy beaches along the entire coastline of the country (De Villiers 2018), sandy beaches along the south coast of South Africa (Nel and Froneman 2015) and in estuaries along the east coast of South Africa (KwaZulu-Natal) (Naidoo et al. 2015). Nel and Froneman (2018) recorded MPs in tube structures of the polychaete *Gunnarea gaimardi* at nine sites along the south coast of South Africa and found MPs in all polychaetes analysed. The average MPs were 0.28 MP particles/g dry weight but the authors did not identify the type of MP found, other than referring to synthetic polymers recorded. Naidoo et al. (2016) reported on plastic ingestion by estuarine mullets (*Mugil cephalus*) in a harbour in Durban (east coast of South Africa). These authors found plastic particles in 73% of fish analysed with an average of 3.8 particles (mainly white fibres) per fish gut.

Given the lack of MPs research in marine biota in South Africa, the aim of this study was to investigate the presence and characteristics of MP particles in mussels in Cape Town, South Africa. Cape Town is situated in the Western Cape province, the fourth largest province in South Africa (StatsSA 2018) that is one of the most popular tourist destinations in the world, contributing 13.3% of tourism in the country in 2012 (Rogerson and Rogerson 2014). As a popular tourism destination, the health of the environment is important to the region as this is one of the main reasons for tourists visiting the area, ie pristine beaches and high aesthetic value of the coastal environment.

## Material and Methods

Mussels (*Mytilus galloprovincialis, Choromytilus meridionalis, Aulacomya ater*) were sampled in October 2018 from 27 sites (15 samples per species if present at each site) in Cape Town, South Africa. The sites extended from the northernmost part of the west coast of the city at Melkbosstrand (33.7193° S, 18.4543° E) to Gordons Bay (34.1515° S, 18.8730° E), the eastern-most extent of False Bay along the south coast of Cape Town (Fig. 1). Mussel samples were collected during spring low tide and placed into Ziploc bags, stored on ice in the field and frozen at −20°C until analysis. The collection, separation and digestion of microplastics in mussels were done according to the protocols used by Li et al. (2015). Briefly, in the laboratory, animals were defrosted, rinsed with distilled water and the byssal threads removed. Mussel soft tissue weight (STW) was measured to the nearest 0.01 g with a Highland® HCB 302 portable precision balance and the total length (TL) of mussels (mm) measured using Vernier callipers. Mussel soft tissue of similar sized mussels were grouped in triplicates to which 10% KOH (w/v) was added to digest the tissue. Five replicates per site were prepared and digested for 24 h at 60°C in a drying oven (model DHG 9070A). The digestates were filtered through a vacuum pump (model Rotary Vane VP 145 1/3 HP) using a 20 µm nylon mesh and allowed to dry before being analysed.

To minimise exposure to ambient microplastics in the laboratory, a cotton white coat was worn during all procedures done in the laboratory. All items used were washed three times with 20 µm filtered distilled water before use and all beakers and containers were covered with foil when being used. All windows and doors in the laboratory were closed during the analyses. Sieves (20 µm mesh) and Ziploc bags without any biological material (n = 8, respectively) were analysed as controls for microplastics and an average of 0.2 microplastics per sieve were recorded (there was no contamination in the Ziploc bags) and the data corrected for ambient contamination accordingly.

Microplastics were visually enumerated using a Zeiss® Stemi DV4 stereo microscope at × 40 magnification and identified using the methods used by Hidalgo-Ruz et al. (2012) and Lusher et al. (2017). The method is subjective and there is potential for incorrect identification of MPs by including natural micro particles, in particular for light coloured fibres (De Villiers (2018). Ideally, analytical methods (e.g., FTIR) should be used to identify MPs, but this was not available at the time of the sample analysis. Careful consideration was taken to count fibres and particles that resembled synthetic characteristics (especially for coloured particles) and to use the hot needle test for particles that were considered synthetic (Lusher et al. 2017). Microplastics were classified according to shape (filament, fragment and sphere), colour (white, transparent, yellow, red/pink, blue/green and black/grey) as well as size (< 0.1, 0.1–0.5, 0.5–1, 1–2, 2–5 and > 5 mm in length). All classification of microplastics are presented as percentages. The total number of microplastics were recorded as MPs per individual as well as MPs per gram wet weight soft tissue. The data was tested before statistical analysis using the Kolmogorov–Smirnov test for normality and the Levene's test for variance. The tests for

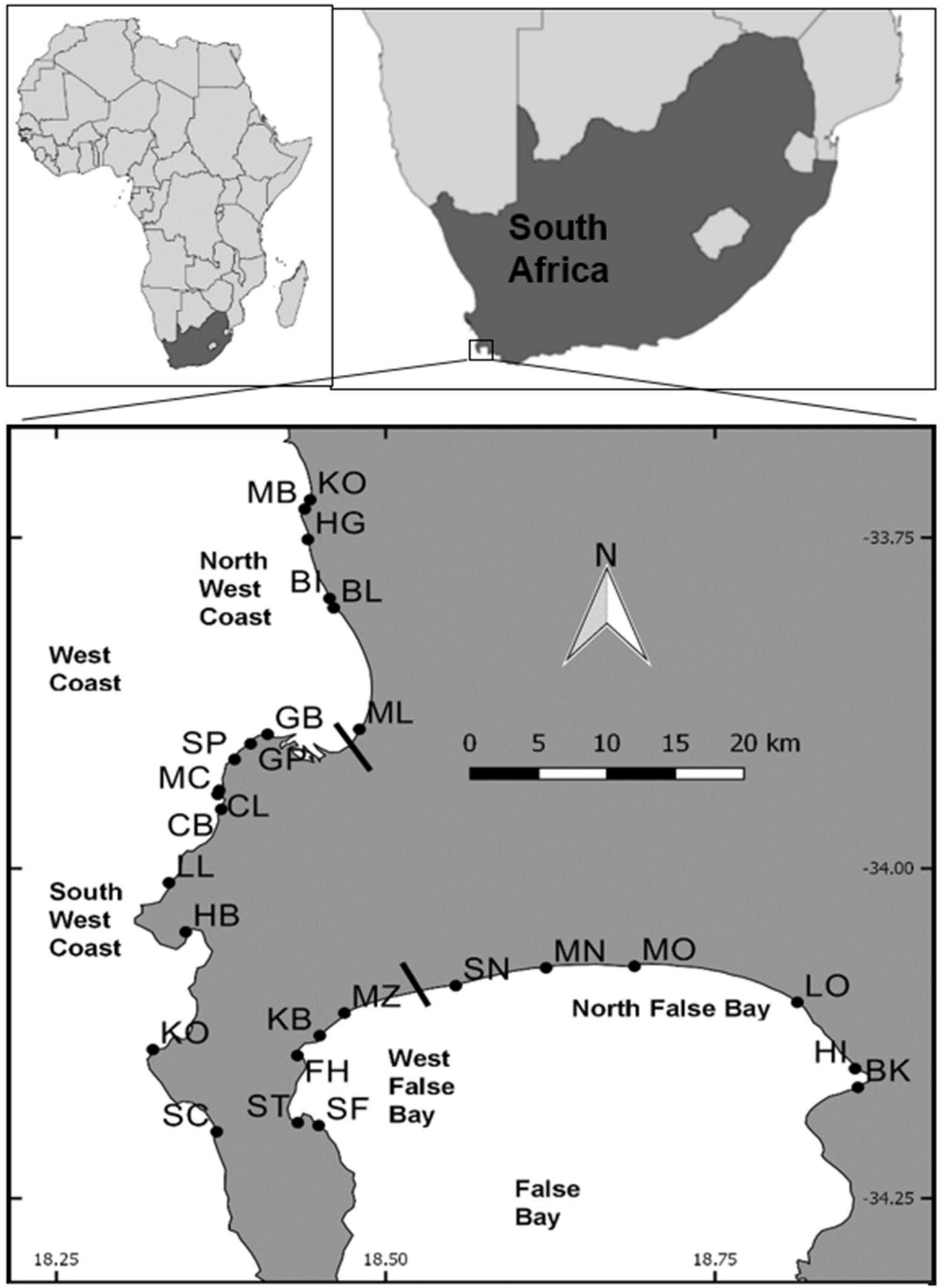


**Fig. 1** MP sampling sites in Cape Town, South Africa

normality were not met (even after log-transformations were done) and non-parametric analyses was conducted on the data using the Kruskal–Wallis test for analysis between more than two groups, a Mann–Whitney (MW) test for two groups. Post hoc analyses for significant differences between sites were done using pairwise comparisons of the Kruskal–Wallis analysis, using the Llandudno site as a control site. Variances of data for statistical analysis was presented using standard error of the mean (SE) and significance of parameters set at $p < 0.05$. All analyses were done using SPSS v25.

## Results and Discussion

Of the 168 mussels analysed, 164 (98%) contained particles resembling microplastics. A total of 1572 particles were recorded, with an average of 2.33 (±0.2) particles/gram and 4.27 (±0.5) particles per mussel. The range of MP abundances were 0–22 particles/gram (wet weight) and 0.3–43 particles/individual for all sites. Regionally, there was a significant difference in MPs between the West Coast and False Bay (MW, $p < 0.05$) (see Fig. 1 for regions). Per sub-region, MP abundances were significantly higher along the North

West Coast than the South West Coast ($p < 0.05$) of Cape Town, with no significant differences recorded between West and North False Bay.

Based on MP per weight, MP particles were significantly ($p < 0.05$) higher than Llundadno (control site) at Milnerton, Lourens River, Mnandi, Melkbosstrand and Maidens Cove (Fig. 2a). MP particles per individual were significantly higher than Llundadno at Simons Town and Lourens River (Fig. 2b).

Based on shape, 67% of MPs were filaments, 21% fragments and 12% spheres (Fig. 3a). Dark colours were most common, with 37% being black or grey and 30% being either blue or green (Fig. 3b). Most MPs were smaller than 1000 µm (27% 100–500 µm, 28% 500–1000 µm and 22% 1000–2000 µm) (Fig. 3c). Shape, colour and size analysis per site showed no clear trends for the different sites (Fig. 4). Of interest is the presence of MPs in mussels at Simons Town (Fig. 4a–c), where the most common shape were fragments, colour was mainly blue/green and the size comprised mainly particles less than 100 µm.

MP analysis was also conducted between *Aulyacoma ater* (ribbed mussel), *Choromytilus meridionalis* (black mussel) and *Mytilus galloprovincialis* (blue mussel) (Fig. 5). There were no significant ($p > 0.05$) differences in either MP per gram or MP per individual between the respective mussel species analysed.

This is the first research to report on MPs in mussels from Cape Town. Compared to other investigations, MPs

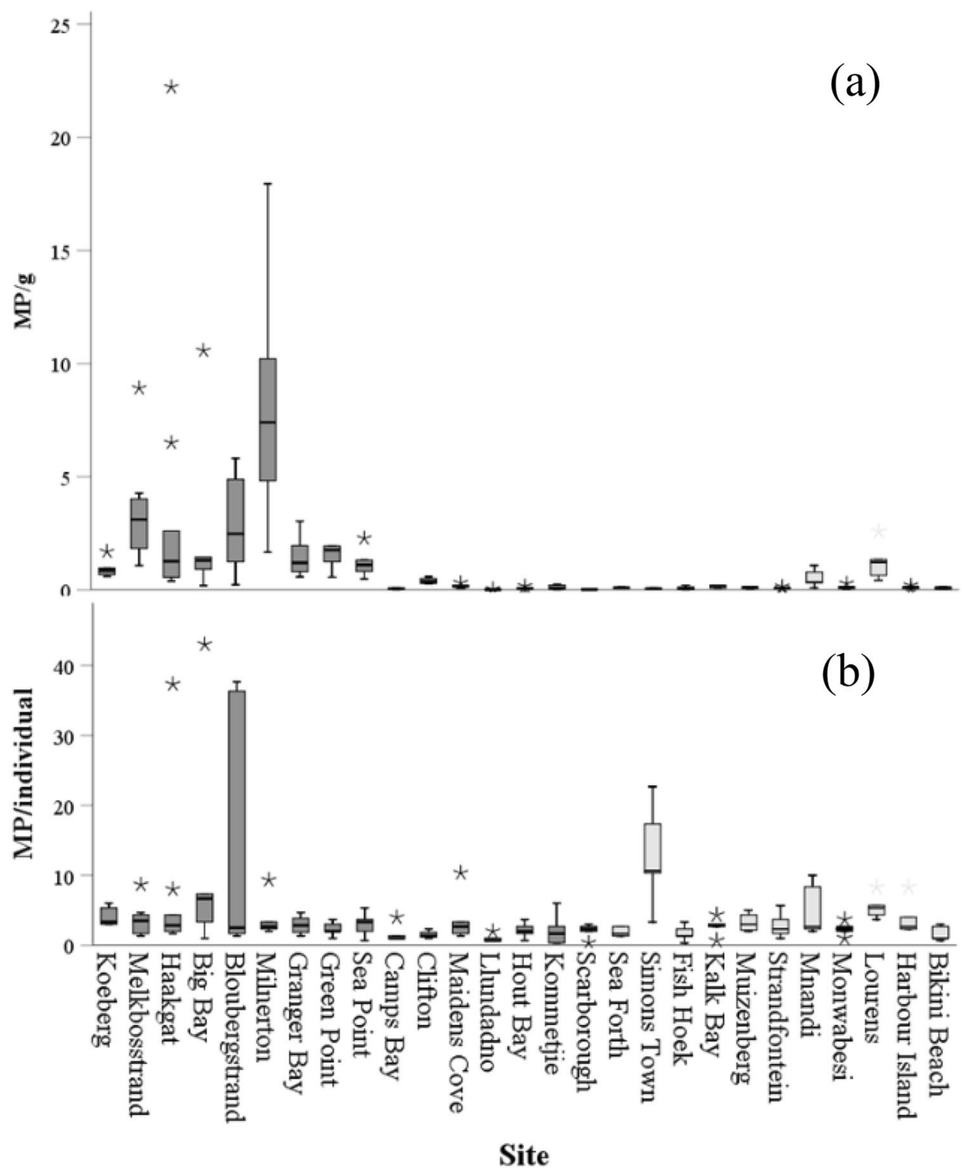


**Fig. 2** Median and inter quartile ranges of microplastic abundances (a: particles per gram soft tissue weight, b: particles per individual) in mussels in Cape Town, South Africa. *indicates outliers; dark grey—West Coast sites and light grey-False Bay sites

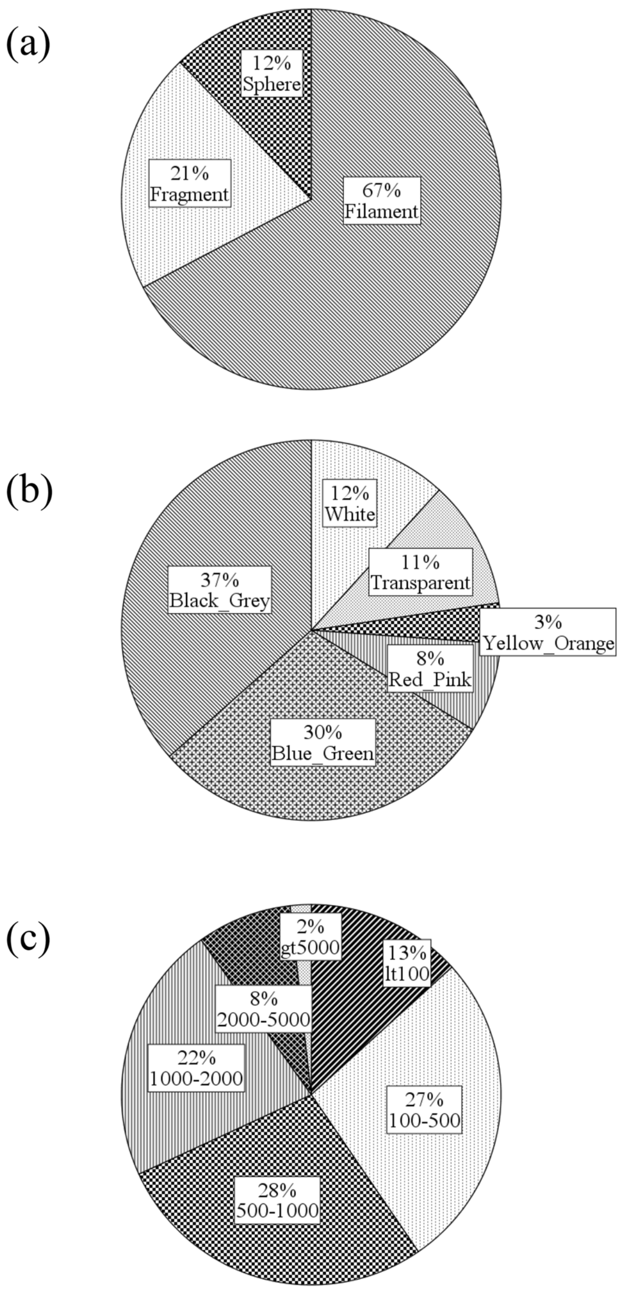


**Fig. 3** Microplastic shapes (**a**), colours (**b**) and sizes (**c**) in mussels sampled in Cape Town, South Africa for all data combined

per individual were higher in Cape Town than in some Chinese areas (Li et al. 2016) and Norway (Lusher et al. 2017) (Table 1). Per weight, MPs in mussels from Cape Town were higher than some Chinese sites (Li et al. 2015, 2016), Norway (Lusher et al. 2017), Germany (Van Cauwenberghe and Janssen 2014), France, Belgium and the Netherlands (Van Cauwenberghe et al. 2015).

MP fibres can comprise up to 91% of plastics collected in global water samples (Barrows et al. 2018), indicating that MP fibres have the potential to be the main type of MPs taken up by marine organisms. MP fibres have been reported to be the dominant MPs in rivers, estuaries, oceans and effluents from wastewater treatment plants (WWTP) (Salvador Cesa et al. 2017). De Villiers (2018) reported that the higher MP fibres recorded in Cape Town was attributed to the close proximity of WWTPs. The present study did not follow MP abundance trends as reported by De Villiers (2018), suggesting that MP uptake by mussels in Cape Town is influenced by numerous factors.

The high MPs recorded at Milnerton could be due to its close proximity to the Rietvlei River mouth. The Rietvlei system includes water coming from the Potsdam WWTP, clothing manufacturers and informal human settlements (Jackson et al. 2009). Another potential source of MPs at the Milnerton site is the Black River mouth, approximately 1 km south of the Milnerton sampling site. Catchment areas linked to the Black River mouth includes the Liesbeek, Salt and Elsies Rivers which run through the Cape Town metropole. These rivers have various sources of MPs (and litter) from a WWTP, storm-water canals, human settlements and various industrial activities (River Health Programme 2005).

High MPs recorded at the Lourens River mouth is attributed to river run-off from the catchment area. The Lourens River system includes MPs from informal human settlements, storm-water canals and industrial activity in the Gordons Bay area (River Health Programme 2003). Mnandi beach had the third highest mean MPs per gram in mussels. This site does not have any riverine input and the high MPs in mussels is attributed to storm-water run-off and high levels of recreational activities (Rundgren 1992).

Highest concentrations of MPs per individual was recorded in Simons Town which was at a marina and within 20 m of boating repairs and maintenance. As the site is a fairly enclosed one, mussels at that site are not exposed to flushing out of waters within the marina. The high MP particles recorded in Simons Town is attributed to waste water from boating maintenance that releases antifouling paint particles (APPs) into the marina. According to Soroldoni et al. (2017), APPs generated in marinas and boatyards end up in the ambient sediment and pose health risks to benthic organisms.

The second and third highest MPs per mussel was recorded at Big Bay and Bloubergstrand. Mussels sampled at Big Bay was close to a shopping centre that has high volumes of pedestrian traffic and beachgoers. The area is also popular for recreational activities and the high MPs recorded at these sites are attributed to human activities. It is also possible that MP fibres from the Green Point marine outfall pipe

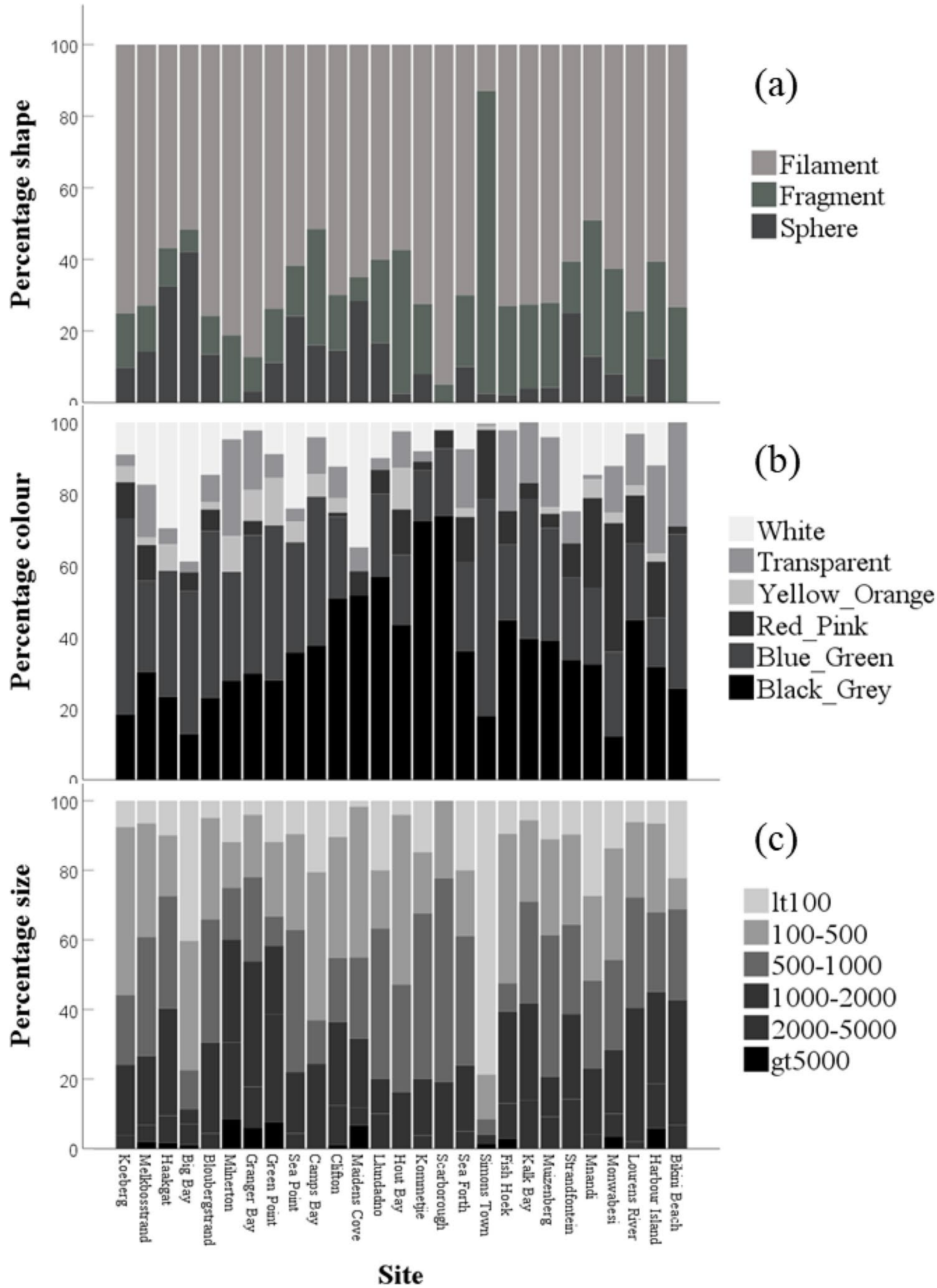


**Fig. 4** Percentage microplastic shapes (**a**), colours (**b**) and sizes (**c**) in mussels sampled per site in Cape Town, South Africa

is reaching the coastline in Big Bay and Bloubergstrand. These sites are downstream from the Green Point marine sewerage outfall pipe that can release up to 44 million litres of sewage waste per day (City of Cape Town 2018). This postulation requires further investigation. Due to the variability of the data at Bloubergstrand and Big Bay (Fig. 2b), the results should be considered with caution.

Ward and Shumway (2004) reported that MP ingestion is highest in filter-feeders, given their efficient ability to take up particles. This is further supported by Woods et al. (2018) where mussels accumulated MP fibres during filter-feeding. Li et al. (2018) suggested that efficient MP uptake was because bivalves are able to take up small particles easily. These laboratory results were confirmed by field studies

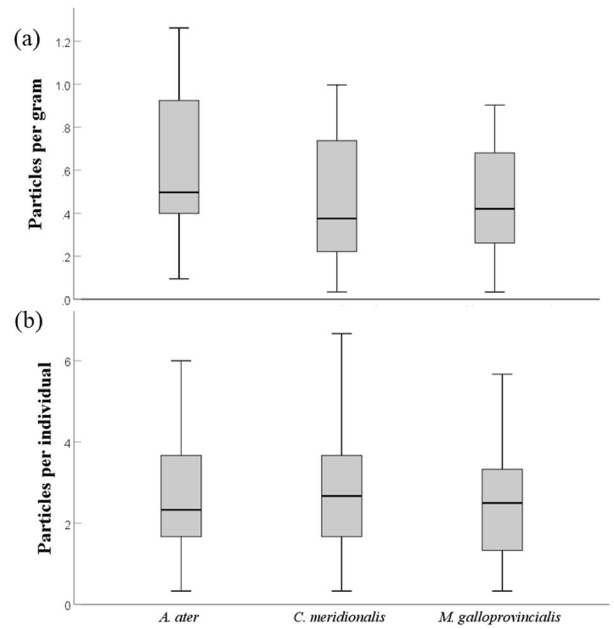


**Fig. 5** MP abundances as particles per gram soft tissue weight (**a**) and particles per individual (**b**) for *A. Ater*, *C. meridionalis* and *M. galloprovincialis* in Cape Town, South Africa

(Leslie et al. 2017) where higher MPs were found in filter-feeders than other types of organisms.

South Africa is ranked 20th in the global rankings of waste produced by countries (tonnes per year) (Silpa et al. 2018). The high waste production is a contributing factor to the high levels of plastic (and litter) and MPs released into coastal environments. The sources of secondary MPs are contentious to mitigate for accountability of environmental degradation in South Africa and, in this context, Cape Town. However, the more important factors to consider are the driving forces affecting the movement and distribution of MPs, such as hydrodynamic forces, wind-induced currents, salinity and biofouling (Barrows et al. 2018). Although accurate identification of MPs was not done in this study (and can be considered a shortcoming of the research), the high abundances and accurate identification of polymer type requires further investigation. The high abundance of secondary MPs (mainly fibrous particles) found in Cape Town mussels provides enough evidence to support the urgent need for starting periodical MP pollution monitoring in South Africa.

**Table 1** Comparisons of average microplastic concentrations in bivalves from this and previous studies

| Species | Country | Microplastic particle// gSTW | Microplastic particle/individual | Common microplastic types | Common microplastic sizes (of total samples) | Common microplastic colour | References |
|---|---|---|---|---|---|---|---|
| *Aulyacoma ater* | South Africa | 2.8 | 2.9 | Fibres | 500–1000 µm (35%) | Black/grey (49%) | This study |
| *Choromytilus meridionalis* | South Africa | 1.8 | 5.6 | Fibres | 100–500 µm (31%) | Blue/green (34%) | This study |
| *Mytilus galloprovincialis* | South Africa | 2.8 | 3.4 | Fibres | 500–1000 µm (29%) | Black / grey (39%) | This study |
| *Mytilus galloprovincialis* | China | 2–12.8 | 1.9–9.6 | Fibres | < 500 µm | Black | Ding et al. (2018) |
| *Mytilus galloprovincialis* | Italy | 8.1 | 6.3 | Fibres | 1150–2290 µm | Black / blue | Renzi et al. (2018) |
| *Mytilus spp* | Norway | 1.85 | 1.84 | Fibres | < 1000 µm | Blue (39%) | Lusher et al. (2017) |
| *Mytilus edulis* | Germany | 0.36 | ND | Fragments | 5–10 µm (50%) | ND | Van Cauwenberghe and Janssen (2014) |
| *Mytilus edulis* | China | 0.9–4.6 | 1.5–7.6 | Fibres | < 250 µm (17%–79%) | ND | Li et al. (2016) |
| Bivalves (Nine species) | China | 2.1–10.5 | 4.3–57.2 | Fibres | < 250 µm (33%–84%) | ND | Li et al. (2015) |
| *Mytilus edulis* | Canada | ND | 34–178 (~ 100 items per control) | Fibres | ND | ND | Mathalon and Hill (2014) |
| *Mytilus edulis* | French, Belgium, Netherlands | 0.2 items/g | ND | Fragments | 20–90 µm | ND | Van Cauwenberghe et al. (2015) |

*ND* no data, *STW* soft tissue weight

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**Conflict of interest** The author declare that they have no conflict of interest.

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