SHORT NOTE

Microplastics in the sediments of Terra Nova Bay (Ross Sea, Antarctica)

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Abstract

This is the first survey to investigate the occurrence and extent of plastic contamination in sediments collected in Terra Nova Bay (Ross Sea, Antarctica). Plastic debris extracted from 31 samples of sediments were counted, weighted and identified by Fourier-transform infrared spectroscopy (FT-IR). All sediment samples contained plastics: a total of 1661 items of debris (3.14 g) were recorded from the 31 samples of sediment. Plastic particles in the samples ranged from 0.3 to 22 mm in length. Fibres were the most frequent type of small plastics debris detected. In terms of abundance, microplastics (<5 mm) accounted for 78.4% of debris. 9 polymer types were found: the most common material (94.13% by weight:) was styrene-butadiene-styrene copolymer (SBS), widely used in pneumatic tires, etc. A decreasing concentration of plastic debris at increasing distances from the Mario Zucchelli Base was evidenced.

Keywords

Microplastics; Polymer composition; Antarctica; Ross Sea; FT-IR spectroscopy

We use more than 320 million tonnes of plastic each year (Plastic Europe, 2016), and discarded "end-of-life" plastic accumulates particularly in marine habitats. There is a heightened awareness of the amount of plastic in the sea, it's spread to even remote localities and the multiple influences of this on organisms, especially for what concerns small fragments and microplastics (plastic particulates < 5 mm; Ivar do Sul and Costa, 2014). Plastic pollution is ubiquitous throughout the marine environment, yet estimates of the abundance and weight of "end-of-life" plastics have lacked data, particularly from the Southern Hemisphere and remote regions. Antarctica is extremely remote and not connected by any land mass, so it could be used as a "reference" for global plastic pollution. The Ross Sea, which comprises 2% of the Southern Ocean, is located between Victoria Land and Marie Byrd Land and is the largest continental shelf ecosystem south of the Antarctic Polar Front. There, the Mario Zucchelli Base is located on a promontory in Terra Nova Bay. It is a scientific research center and a strategic logistics node for other bases in Antarctica. From 1985, when it was built, until now the station hosted 33 scientific expeditions, with an average of 300 researchers a year. Taking into account the early stages of studies dealing with plastic deposition in Antarctic marine sediments, with the present study we wanted to assess, for the first time in Terra Nova Bay (Ross Sea), the quality and quantity of small plastic debris occurring in sediments to address the gap in knowledge and to serve as a baseline for future comparisons.

In the austral summer 2015, during the 30th Antarctic Expedition (PNRA, Italian Research Program in Antarctica), sediment samples were taken from Terra Nova Bay, Ross Sea (Fig. 1). The sampling program was carried out aboard the MS "Malippo" in January 2015, and sediment samples were taken with a Van Veen grab (surface 0.18 m^2). A total of 11 stations were sampled at increasing distance from the Mario Zucchelli Base: 3 stations at Adelie Cove (10 km south of the base), at 25, 70 and 140 m depth (Stns AC25, AC70, AC140), 1 station at Central Bay (7 km south of the base; Stn CB25), 3 stations at Camp Icarus (4 km south of the base; Stns CI25, CI70, CI140), 3 stations at Rod Bay (2 km south of the base; Stns RB25, RB70, RB140), and finally 1 station in front of the Mario Zucchelli Base (Stn SMZ25). Each station was sampled in triplicate, except for SMZ25 and

CB25, where adverse weather conditions allowed to collect only 2 replicates. At each station, further sediment cores were taken for sediment characterization (with the exception of SMZ25 and CB25). Sampling stations coordinates are reported in Table 1.

At our laboratories, the plastic debris in sediment samples were removed under a dissection microscope (Nikon SMZ45T, magnification 3.35-300x), counted and weighted to the nearest 0.0001 g. The identified plastics were measured at their largest cross-section using calipers and classified into three groups: micro (≤5 mm), meso (>5–20 mm), and macro (>20 mm) (Jayasiri et al., 2013). Plastic debris were also categorized according to shape (i.e., fibre, film, fragment). Plastic debris composition at the 11 stations was investigated by means of ordination analysis (nMDS) based on the Bray-Curtis similarity index calculated on untransformed quantity data. Plastic categories contributing to dissimilarity between stations were investigated using the similarity percentages (SIMPER) analysis (Clarke 1993). Differences in plastic debris composition and quantity between stations were analyzed through PERMANOVA (Anderson et al., 2008) according to a one-way experimental design. For the one-way case, an exact P-value was provided using unrestricted permutation of raw data. When low unique values in the permutation distribution were available, asymptotical Monte Carlo P-values were used instead of permutational P-values. All the analyses were performed using PRIMER 6 and PERMANOVA+ (Anderson et al., 2008). Fourier-transform infrared spectroscopy (FT-IR) analysis of 20 plastic debris randomly selected for each shape type was carried out with a CARY 600 FT-IR (Agilent Technologies) instrument. Measurements were carried out in attenuated total reflectance (ATR) configuration, with a Pike Miracle diamond cell. Tests were carried out at 25°C in dry air. Particles were identified by comparing FT-IR absorbance spectra of the microplastics to those in a self-collected, polymer reference library.

A total of 31 sediment samples were analyzed from the 11 stations. Some examples of plastic debris collected during the study are shown in Fig. 2. All sediment samples contained plastics. A total of 1661 items of debris (3.14 g) were recorded from the 31 samples of sediment. Samples contained between 5 and 1705 plastic debris m^{-2}. The size of plastic particles in the samples ranged from 0.3 to 22 mm in length, with microplastics being classified as those smaller than 5 mm, with the most common size being 2-3 mm. The samples contained both fibres, film and fragments in a range of colors, implying that particles may have originated from multiple sources including the degradation of larger plastic objects. The greatest plastic abundance by number and weight was observed at RB25 (676.5 ± 536.4 debris m^{-2} and 3.03 ± 2.85 g m^{-2}, respectively). In contrast, the lowest mean values by number and weight were 12.83 ± 12.04 debris m^{-2} and 0.004 ± 0.006 g m^{-2} at AC25. The primary shape types by number (Fig. 3) were fibres (42.8%), followed by film (35%), and fragments (22.2%). In Table 2 the average abundance of shape type of plastics collected is shown. Ordination analyses through nMDS showed a distance gradient in concentration of shape types (Fig. 4a) and size (Fig. 4b) of plastics, whose ends are shallower-depth stations close to the Mario Zucchelli Base (right side of the plots), and those at Adelie Cove (left side of the plots). Deeper stations were mostly segregated in the center of the plots. This result was confirmed by PERMANOVA (Table 3). As the number of unique values under permutations was very low, P-values were obtained using Monte Carlo samples from the asymptotic permutation distribution. Pairwise tests (Supplementary Materials, Tables S1 and S2) evidenced significant differences between AC and MZS stations. Similarity percentages analysis (SIMPER) showed that the concentration of fibres and microplastics (Supplementary Materials, Tables S3 and S4) mainly drove the differences between stations. There was greater abundance of microplastics compared to meso and macro debris (Table 4). This was reflected in the frequency distribution of different sizes of debris (Fig. 5). In terms of numerical abundance, microplastics accounted for 78.4% of the total amount found, mesoplastics made up 19.9% of total amount, while macro debris accounted for 1.7%. Identification through FT-IR spectroscopy evidenced the presence of 9 polymer types: polyethylene (PE), polypropylene (PP), Nylon 6.6 (Nylon), polystyrene-butadiene-styrene (SBS), polyvinyl chloride (PVC), polystyrene (PS), thermoplastic polyurethane (TPU), polyvinyl alcohol (PVA), and ethylene-propylene rubber (EPR). At sampling sites closer to the Mario Zucchelli Base (e.g. SMZ25, RB25), the majority of plastic debris were SBS, while at the most distant sites (e.g. Adelie Cove) it was Nylon. The composition by polymer type is shown in Fig. 6a, and by weight in Fig. 6b.

There are to date very few reports of the presence of plastics in Antarctica. Plastic debris have been found in sediments from Amundsen and south Bellingshausen seabed (Barnes et al., 2010), from the Weddell Sea (Van Cauwenberghe et al., 2013), and from South Shetland Islands (Waller et al., 2017), in the surface waters of the Pacific sector of the Southern Ocean (Isobe et al., 2017), and of the Ross Sea (Cincinelli et al., 2017). The latter authors investigated for the first time the occurrence of plastics in surface waters of the Ross Sea, and found microplastics ranging from 0.0032 to 1.18 particle per m^3 of seawater. Our survey at 11 stations in Terra Nova Bay recorded a total of 1661 plastic items. The abundance of plastic debris showed an evident difference between their number found in the samples collected nearby anthropogenic activities (the Mario Zucchelli Base) and those from farther areas (e.g. Adelie Cove). The heterogeneity of plastics at our sampling sites may be caused by several factors, such as proximity to research activities in the coastal area, ship traffic, transportation by means of ocean currents and others. Isobe et al. (2017), investigating the amount of pelagic microplastics in the Southern Hemisphere, suggest that microplastics are likely to be trapped around Antarctica once they are transported beyond the Antarctic Circumpolar Current and Polar Front. In their review, Waller et al. (2017) reported that 52% of the research stations located in Antarctica had no wastewater treatment systems, and quantified the human presence in the region, onboard ships and at scientific research stations as ~18.2×10^6 person days per decade. Cincinelli et al. (2017), monitoring pelagic microplastics in the Ross Sea, found the highest concentration in the sample collected close to the effluent of the conventional sewage treatment plant at Mario Zucchelli Base. At all our sampling stations, microplastics comprised the majority of the plastic debris (78.4%), with a declining plastic size with increasing plastic debris abundance. Barnes et al. (2009) reported a generalized decrease in the mean size of plastic debris in the global environment, along with the increasing abundance of such particles due to continuous degradation. In the sediments of Terra Nova Bay, the most common material (94.13% by weight:) was styrene-butadiene-styrene copolymer (SBS). This is a thermoplastic elastomer having similar properties to traditional vulcanized rubbers, but considerably less expensive in manufacturing, and thus produced in considerable quantities (5.4 million tonnes in 2012). It is widely used in pneumatic tires, gaskets, soles of shoe, waterproofing systems, coated papers, and other places where durability is important. Given their small size, it was obviously impossible to identify the objects that generated SBS debris found in sediments. We found however a clear dominance of SBS debris at stations closer to the scientific base (stations SMZ, RB, CI; Fig. 6b), and this may further confirm an impact arising from anthropic activities carried out in the area of the scientific base.

This study represents a baseline for microplastic research in the coastal sediment compartment in the Terra Nova Bay (Antarctica). We sampled 11 stations at different depths for small plastic debris and we found all stations to be contaminated. Our 2015 survey showed that plastic debris were common and quite abundant in the sediments of Terra Nova Bay, particularly in areas potentially affected by the influence of the scientific Mario Zucchelli Base. Our results raise concern about the widespread nature of marine microplastic pollution, indicating that plastic-free ocean environments are increasing rare. Despite their young age, as have only been produced for the past 60 years. plastics have already invaded most marine habitats, and even the most pristine of environments, the Antarctic seabed is not been spared, as this study shows.

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Figure Legend

Fig. 1 Map of study sites.

Fig. 2. Examples of the collected plastic debris (from station RB70).

Fig. 3. Composition of plastic debris collected according to shape type.

Fig. 4. Ordination plots through nMDS of (a) shape types, and (b) size data of plastic debris.

Fig. 5. Composition of plastic debris collected according to size: Micro (≤5 mm), Meso (>5–20 mm), and Macro (>20 mm).

Fig. 6. Composition of plastic debris collected at the 11 sampling sites according to (a) type of polymer, and (b) weight (polyethylene: PE, polypropylene: PP, Nylon 6.6: NYL, polystyrene-butadiene-styrene: SBS, polyvinyl chloride: PVC, polystyrene: PS, thermoplastic polyurethane: TPU, polyvinyl alcohol: PVA, ethylene-propylene rubber: EPR).

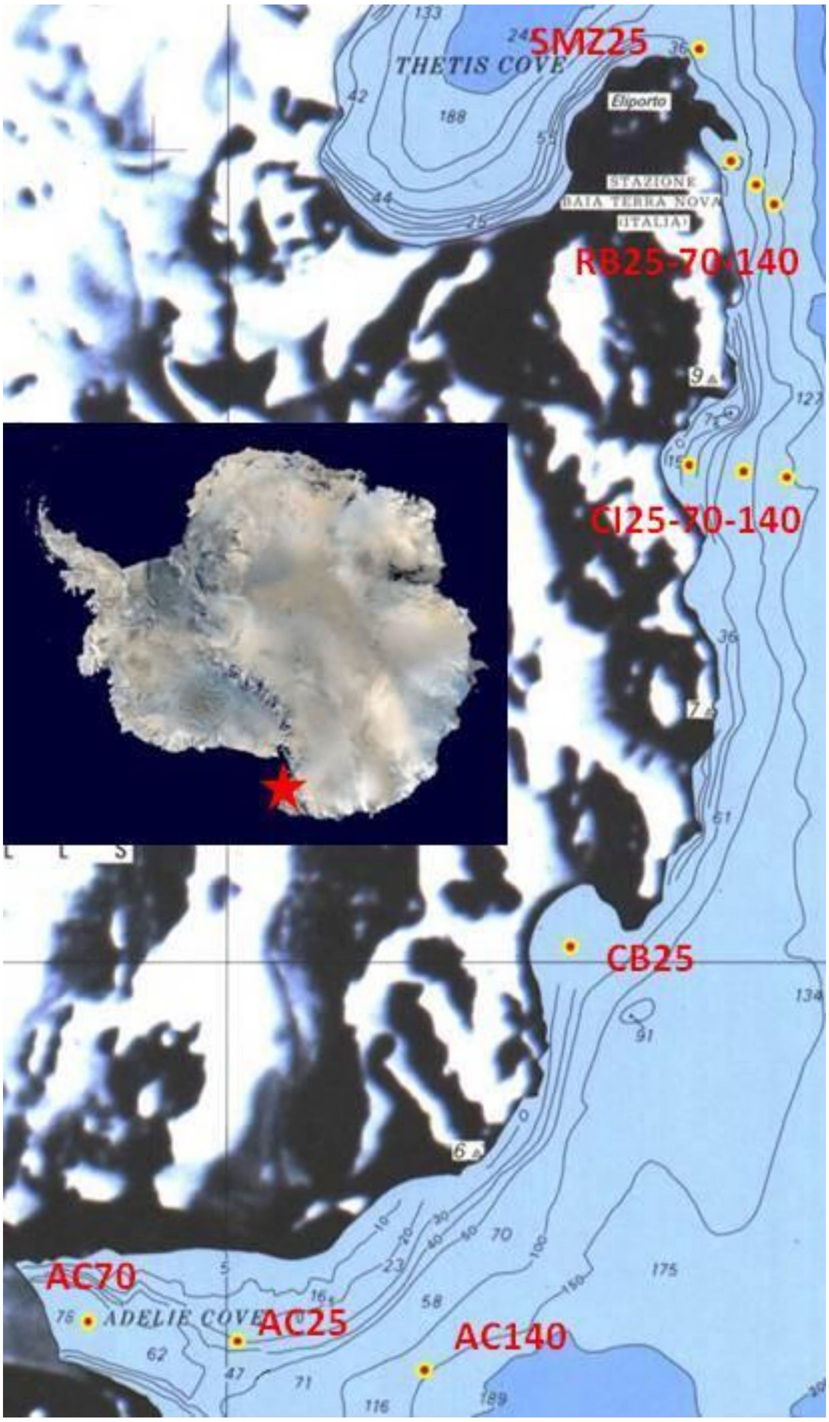

SMZ25
THETIS COVE
Eliporto
STAZIONE
BAIA TERRA NOVA
(ITALIA)
RB25-70-140
CI25-70-140
CB25
AC70
ADELIE COVE
AC25
AC140

Fig. 1

Fig. 2

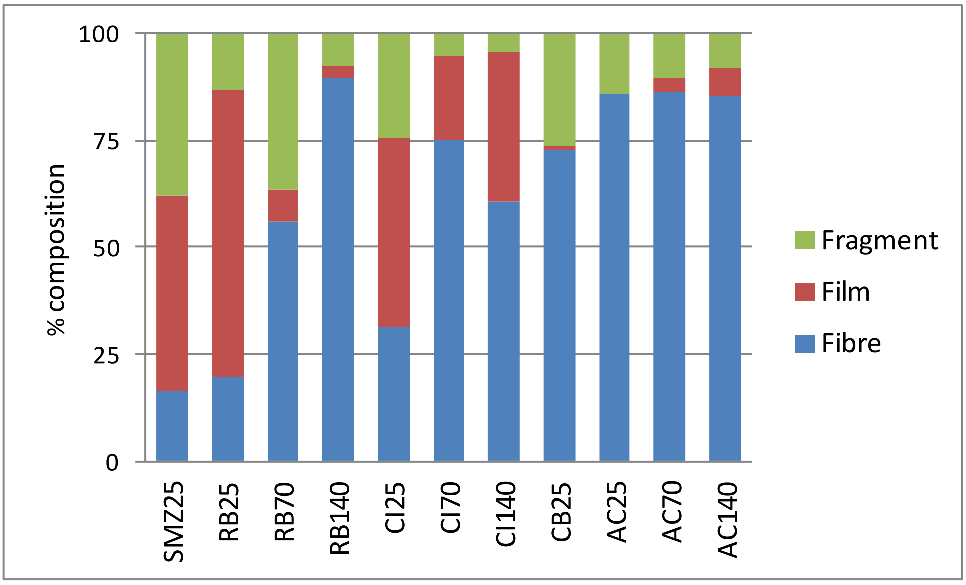
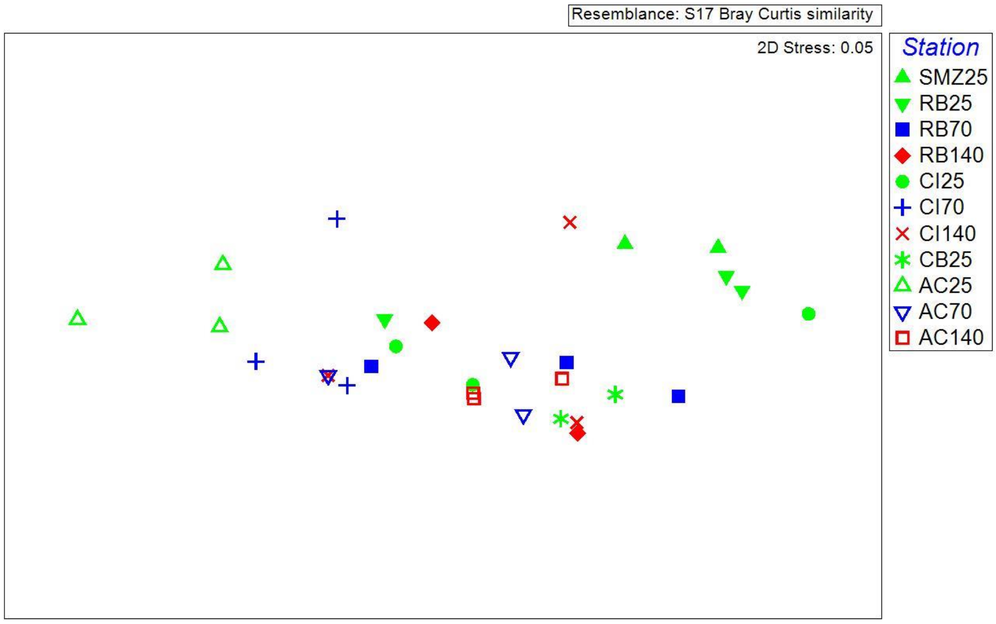
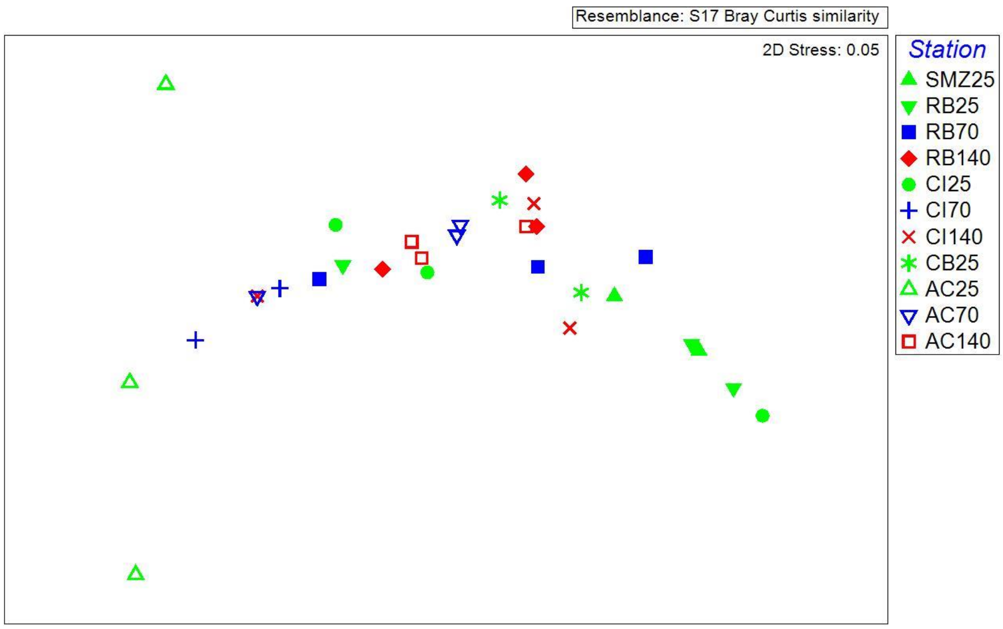

100
75
50
25
0
% composition
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140
Fragment
Film
Fibre

Fig. 3


Resemblance: S17 Bray Curtis similarity
2D Stress: 0.05
Station
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140

(a)


Resemblance: S17 Bray Curtis similarity
2D Stress: 0.05
Station
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140

(b)

Fig. 4

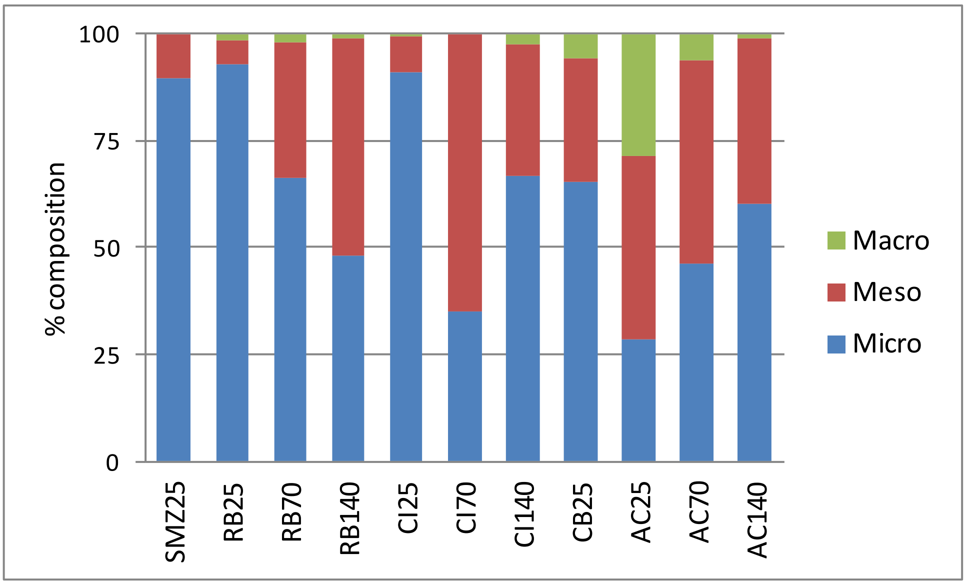
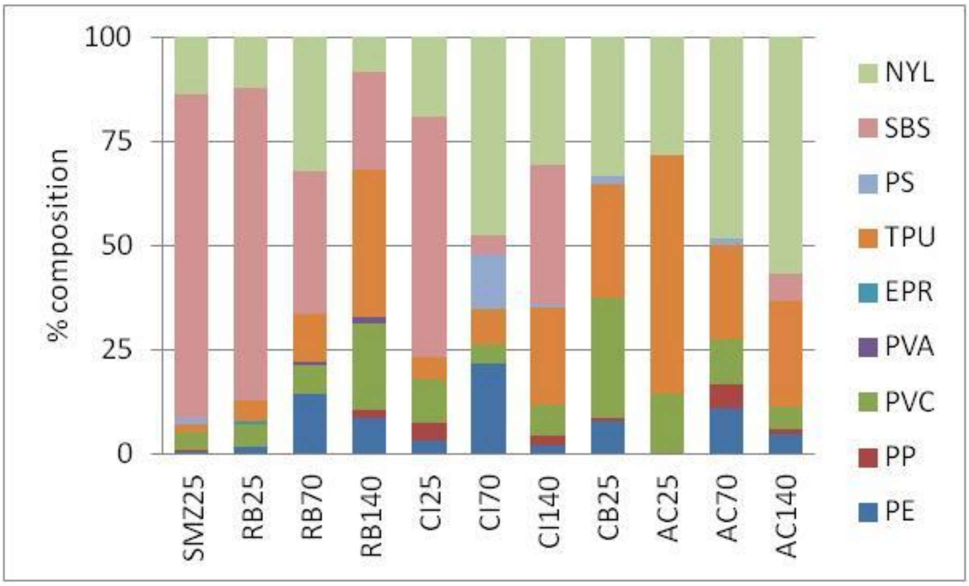
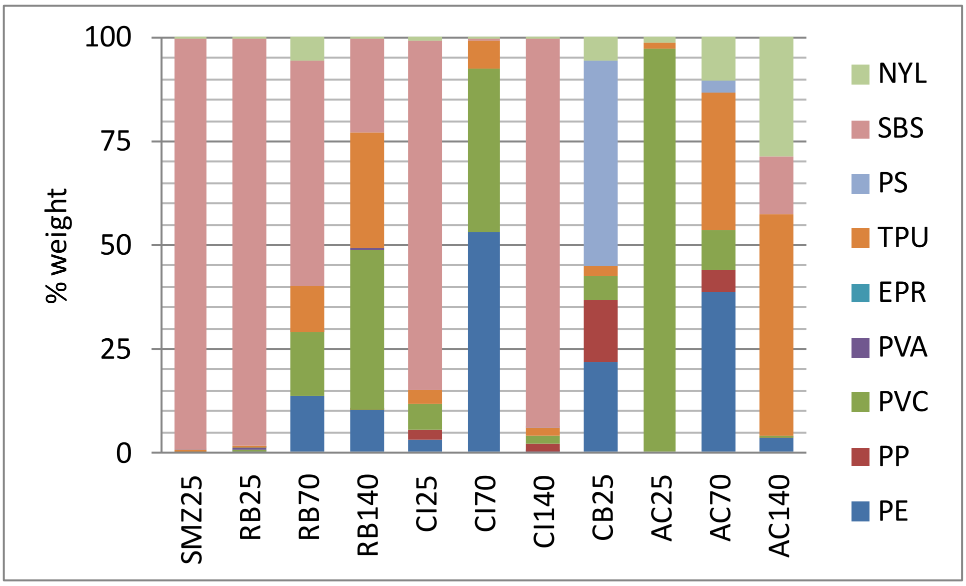

100
75
50
25
0
% composition
Macro
Meso
Micro
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140

Fig. 5


100
75
50
25
0
% composition
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140
NYL
SBS
PS
TPU
EPR
PVA
PVC
PP
PE

(a)


100
75
50
25
0
% weight
SMZ25
RB25
RB70
RB140
CI25
CI70
CI140
CB25
AC25
AC70
AC140
NYL
SBS
PS
TPU
EPR
PVA
PVC
PP
PE

(b)

Fig. 6

Table 1.
Sampling stations coordinates and depth (MZS: M. Zucchelli Base; RB: Rod Bay; CI: Camp Icarus; CB: Central Bay; AC: Adelie Cove).

Station	Latitude S	Longitude E	Depth (m)
SMZ25	74°41.335	164°07.098	25
RB25	74°41.831	164°07.532	25
RB70	74°41.918	164°07.896	70
RB140	74°41.972	164°08.208	140
CI25	74°43.037	164°06.908	25
CI70	74°43.078	164°07.757	70
CI140	74°43.101	164°08.399	140
CB25	74°44.925	164°05.243	25
AC25	74°46.390	163°57.977	25
AC70	74°46.467	164°00.266	70
AC140	74°46.617	164°02.798	140

Table 2.
Shape type of plastics collected. Values represent average abundance (number of items *per* square meter) and standard deviation (in italics).

Location	**Site**	**Fibre**	**Film**	**Fragment**
M. Zucchelli Base	SMZ25	19.50	55.50	45.50
		4.95	*44.55*	*9.19*
Rod Bay	RB25	24.33	82.67	16.00
		15.31	*69.92*	*15.39*
	RB70	31.67	4.33	20.67
		23.50	*4.04*	*27.30*
	RB140	34.67	1.00	3.00
		19.63	*1.73*	*1.73*
Camp Icarus	CI25	38.00	53.00	29.67
		42.79	*90.93*	*46.20*
	CI70	5.00	1.33	0.33
		2.65	*2.31*	*0.58*
	CI140	23.00	13.33	1.67
		20.42	*21.39*	*2.08*
Central Bay	CB25	39.00	0.50	14.00
		0.00	*0.71*	*14.14*
Adelie Cove	AC25	2.00	0.00	0.33
		1.00	*0.00*	*0.58*
	AC70	19.33	0.67	2.33
		11.59	*1.15*	*3.21*
	AC140	25.00	2.00	2.33
		8.66	*2.65*	*3.21*

Table 3.
Results of PERMANOVA main test on unrestricted permutation of raw data.

	Source	*df*	*SS*	*MS*	*Pseudo-F*	*P(perm)*	*P(MC)*
Shape type	Stns	10	33451	3345.1	2.0683	0.0059	0.0073
	Res	20	32346	1617.3			
	Total	30	65797				
Dimension	Stns	10	30867	3086.7	1.822	0.0201	0.0195
	Res	20	33882	1694.1			
	Total	30	64750				

Table 4.

Dimension of plastics collected. Values represent average abundance (number of items *per* square meter) and standard deviation (in italics)

(micro: <5mm; meso: from 5 to 20 mm; macro: > 20mm).

Location	Site	Micro	Meso	Macro
M. Zucchelli Base	SMZ25	108.00	12.50	0.00
		57.98	*0.71*	*0.00*
Rod Bay	RB25	114.00	7.00	2.00
		94.17	*6.08*	*2.00*
	RB70	37.67	18.00	1.00
		33.65	*16.37*	*1.73*
	RB140	18.67	19.67	0.33
		8.62	*14.05*	*0.58*
Camp Icarus	CI25	109.67	10.33	0.67
		168.36	*11.85*	*1.15*
	CI70	2.33	4.33	0.00
		1.15	*1.15*	*0.00*
	CI140	25.33	11.67	1.00
		24.58	*12.42*	*1.73*
Central Bay	CB25	35.00	15.50	3.00
		24.04	*4.95*	*4.24*
Adelie Cove	AC25	0.67	1.00	0.67
		1.15	*1.00*	*0.58*
	AC70	10.33	10.67	1.33
		7.23	*5.13*	*1.15*
	AC140	17.67	11.33	0.33
		6.43	*8.39*	*0.58*