

2019-03-05

Deep sea sediments of the Arctic Central Basin: A potential sink for microplastics

Kanhai, LDK

<http://hdl.handle.net/10026.1/13647>

10.1016/j.dsr.2019.03.003

Deep Sea Research Part I: Oceanographic Research Papers

Elsevier

All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.

1 Disclaimer

2 'This is a copy of the accepted paper as submitted for publication. Readers are advised to refer to the
3 final version of the paper which can be found at

4 <https://www.sciencedirect.com/science/article/pii/S0967063718301973?via%3Dihub>

5

6

7 **Deep sea sediments of the Arctic Central Basin: A potential sink for microplastics**

8 La Daana K. Kanhai^{a*}, Carina Johansson^b, J.P.G.L. Frias^c, Katarina Gardfeldt^d, Richard C.
9 Thompson^e, Ian O'Connor^a

10 ^aDepartment of Life Sciences, The University of the West Indies, St. Augustine, Trinidad and
11 Tobago

12 ^bDepartment of Geological Sciences, Stockholm University, Sweden

13 ^cMarine and Freshwater Research Centre, Galway Mayo Institute of Technology, Dublin Road,
14 Galway, Ireland

15 ^dDepartment of Chemistry and Chemical Engineering, Chalmers University of Technology,
16 Göteborg, SE-412 96, Sweden

17 ^eMarine Biology and Ecology Research Centre, School of Biological and Marine Sciences,
18 University of Plymouth, Drake Circus, Plymouth, Devon PL4 8AA, United Kingdom

19

20 **Abstract**

21 Deep sea sediments have in the past decade emerged as a potential sink for microplastics in the
22 marine environment. The discovery of microplastics in various environmental compartments of
23 the Arctic Central Basin (ACB) suggested that these contaminants were potentially being
24 transported to the deep-sea realm of this oceanic basin. For the first time, the present study
25 conducted a preliminary assessment to determine whether microplastics were present in surficial
26 sediments from the ACB. Gravity and piston corers were used to retrieve sediments from depths
27 of 855 – 4353 m at 11 sites in the ACB during the Arctic Ocean 2016 (AO16) expedition. Surficial
28 sediments from the various cores were subjected to density flotation with sodium tungstate
29 dihydrate solution ($\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$, density 1.4 g cm^{-3}). Potential microplastics were isolated and
30 analysed by Fourier Transform Infrared (FT-IR) spectroscopy. Of the surficial samples, 7 of the
31 11 samples contained synthetic polymers which included polyester ($n = 3$), polystyrene ($n = 2$),

32 polyacrylonitrile (n = 1), polypropylene (n = 1), polyvinyl chloride (n = 1) and polyamide (n = 1).
33 Fibres (n = 5) and fragments (n = 4) were recorded in the samples. In order to avoid mis-
34 interpretation, these findings must be taken in the context that (i) sampling equipment did not
35 guarantee retrieval of undisturbed surficial sediments, (ii) low sample volumes were analysed (~
36 10 g per site), (iii) replicate sediment samples per site was not possible, (iv) no air contamination
37 checks were included during sampling and, (v) particles <100 µm were automatically excluded
38 from analysis. While the present study provides some preliminary indication that microplastics
39 may be accumulating in the deep-sea realm of the ACB, further work is necessary to assess
40 microplastic abundance, distribution and composition in surficial sediments of the ACB.

41

42 **Keywords:** Microplastic, Marine debris, Arctic Ocean, Sediment, Deep Sea

43 *Corresponding Author Email Address: ladaanakada@yahoo.com

44

45 **1. Introduction**

46 Microplastics are pervasive, persistent contaminants in the world's oceans that warrant concern
47 due to the potential threat they pose to marine organisms. Traditionally, microplastic sampling has
48 been conducted in surface and near-surface waters due to the presumption that the majority of
49 microplastics would be present in that layer of the water column. However, when plastic
50 production and projected plastic input to the ocean was considered, there was an evident mismatch
51 between reported and expected plastic concentrations in surface oceanic waters (Cózar et al. 2014;
52 Eriksen et al. 2014). It was therefore apparent that apart from surface waters, microplastics were
53 present in various environmental compartments in the world's oceans (water column, sea ice,
54 sediments, biota) and that some of these potentially functioned as sinks (Obbard et al. 2014;
55 Woodall et al. 2014). Deep sea sediments have recently been identified as a potential sink for
56 microplastics (Woodall et al. 2014; Bergmann et al. 2017). To date, only a few studies have
57 reported on microplastics in deep sea sediments in various oceanic basins (Van Cauwenberghe et
58 al. 2013; Woodall et al. 2014; Fischer et al. 2015; Bergmann et al. 2017). Despite the fact that each
59 of these studies employed different sampling equipment, extraction techniques and reported
60 microplastic abundance in different units, the consensus was that microplastics have made it to the
61 deep-sea and that they are pervasive in its sediments. Presently, uncertainty still exists regarding

62 the exact mechanisms that are responsible for the vertical transport of microplastics out of surface
63 oceanic waters and into deep sea sediments.

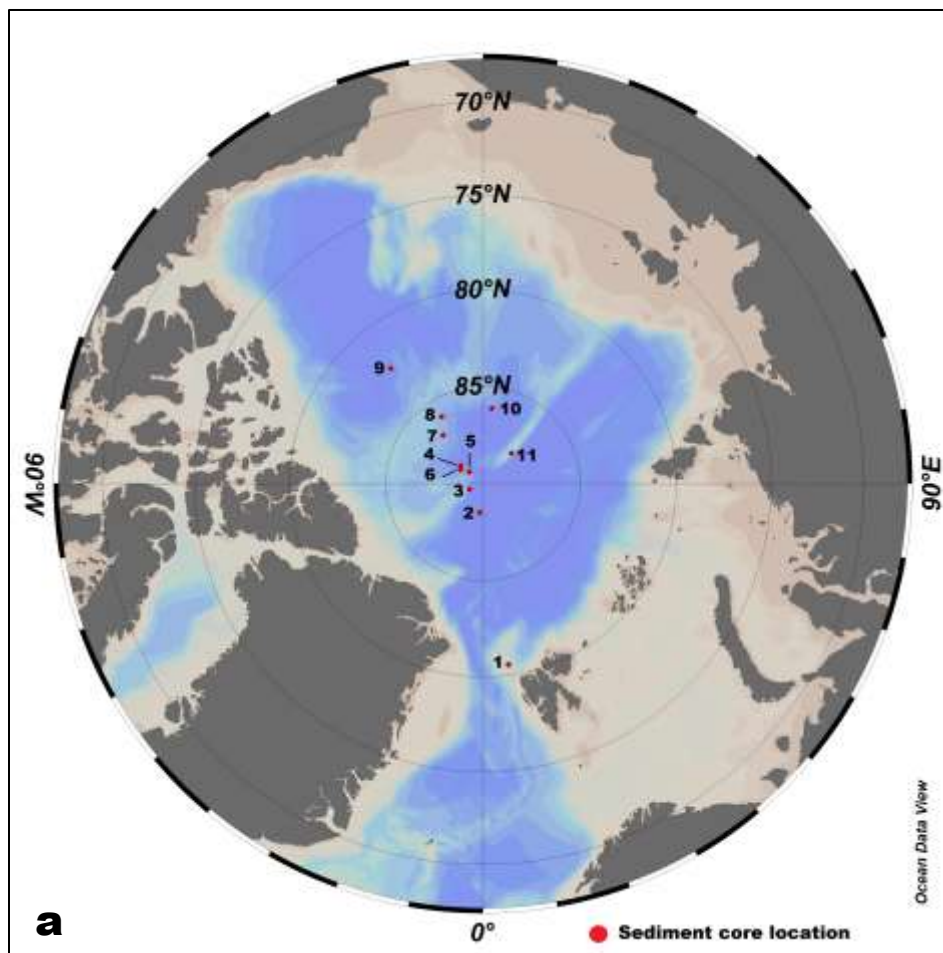
64
65 The Arctic Ocean, though one of the most remote oceanic basins in the world, has been subject to
66 the entry of plastic debris into its ecosystem. It has been suggested that this plastic debris, in
67 particular microplastics, could have entered the Arctic ecosystem via a combination of (i) long-
68 range transport processes, e.g. via oceanic currents (Zarfl and Matthies 2010; van Sebille et al.
69 2012), biotransport (Mallory 2008; Provencher et al. 2012) and riverine input (Obbard et al. 2014)
70 and, (ii) local anthropogenic activities, e.g. shipping (Tekmann et al. 2017). Specifically,
71 microplastics were discovered in the surface/sub-surface waters and sediments (Lusher et al. 2015;
72 Bergmann et al. 2017; Cózar et al. 2017; Mu et al. 2019) of the Arctic. Further north, in the Arctic
73 Central Basin (ACB), microplastics were recorded in sea ice, biota, such as juvenile polar cod
74 (*Boreogadus saida*) and benthic organisms, and sub-surface waters (Obbard et al. 2014; Kanhai et
75 al. 2018; Kuhn et al. 2018; Peeken et al. 2018; Fang et al. 2018). The fact that microplastics have
76 been reported in the various water layers of the ACB, in particular its deep waters, suggests that
77 these particles are pervasive in the water column and that they are being transported out of its
78 surface waters (Kanhai et al. 2018). It was therefore hypothesized that microplastics would be
79 present in deep sea sediments in the ACB. To our knowledge, the present study sought for the first
80 time to determine whether microplastics were present in surficial sediments of the Arctic Central
81 Basin (ACB) and to establish whether the deep sea in this oceanic basin is possibly acting as a sink
82 for microplastics.

83 84 **2. Material and methods**

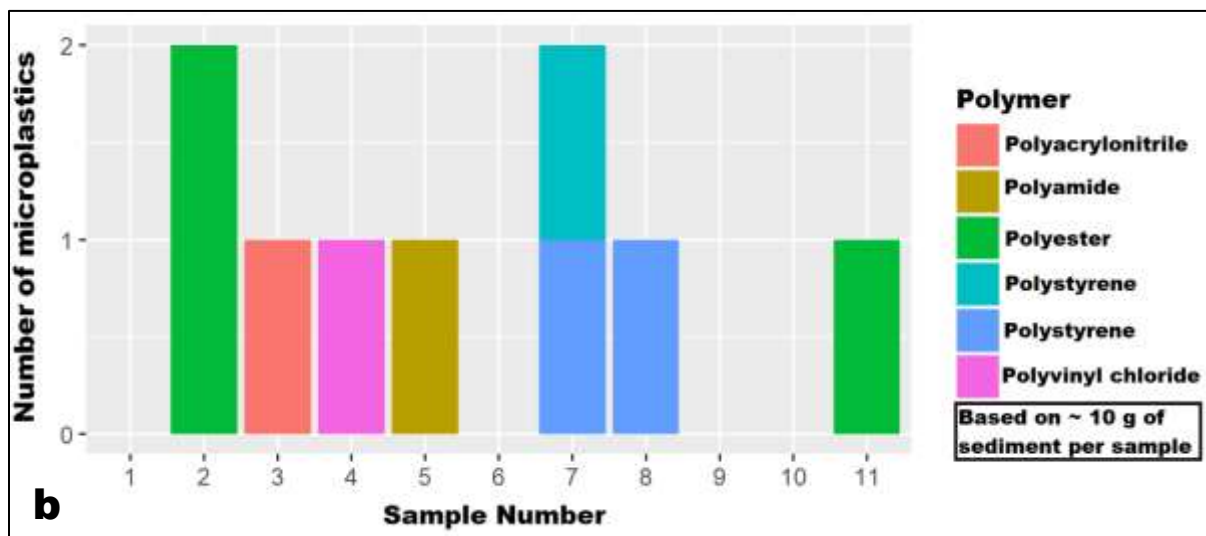
85 The Arctic Ocean, the world's smallest ocean, is comprised of a deep central basin surrounded by
86 extensive continental shelves. The bathymetry of the Arctic Ocean is such that the Lomonosov
87 Ridge divides the central basin into the Canadian (Amerasian) and Eurasian sub-basins (Jakobsson
88 et al. 2004). Within each of the sub-basins, there are further divisions as well as the existence of
89 Abyssal Plains (APs) which are deep water areas of low relief. In the Amerasian basin, the Alpha-
90 Mendeleev Ridge separates the Canada Basin (with its Canadian AP) and the Makarov Basin (with
91 its Fletcher AP) while in the Eurasian basin, the Gakkel Ridge separates the Amundsen Basin (with
92 its Pole AP) and the Nansen Basin (with its Barents AP), (Jakobsson et al. 2004).

93

94 This study was conducted onboard the Swedish icebreaker Oden between August 8th to September
95 19th 2016 during the Arctic Ocean 2016 expedition. During the transit of 4943 nautical miles,
96 sediments were retrieved using a gravity corer or a piston corer with an associated trigger weight
97 corer. Cores from 11 stations were sampled for microplastics (Supplementary Table 1, Figure 1).



98



99

100 Figure 1: Locations at which sediment cores were collected in the Arctic Central Basin (a) and
 101 synthetic polymer composition in surficial sediments from the various cores (b).

102 [Figure 1a generated using Ocean Data View (ODV) Version 4.7.10 (Schlitzer 2017); Figure 1b
 103 generated using R version 3.4.4 (R Core Team 2018)]

104

105 Cores were split, wrapped in plastic film (polyethylene) and transported to the laboratory where
106 they were processed prior to sampling for microplastics. Processing usually involved (i) scraping
107 the core half (with a polypropylene scraper) to remove liner fragments and sediment disturbed
108 during core splitting and, (ii) visually describing the lithostratigraphic properties. Sheer strength
109 measurements, sediment pH and samples for paleomagnetic measurements were taken prior to
110 microplastic sampling for four of the eleven cores (gravity and piston cores). Approximately 10
111 cm³ of sediment was sampled from the top 2 cm of the working half of each core using a scoop
112 (polypropylene). Sediment samples were placed into clean, labelled plastic bags (polyethylene)
113 and stored in a freezer (-20°C).

114

115 Although it is acknowledged that such a low volume of sediment may not be representative of
116 sediments at individual sampling stations, the sampling technique used in the present study, i.e.
117 coring, limited the volume of sediment that was available per site. Precautions taken onboard the
118 ship to limit cross-contamination included (i) minimal exposure of the sediment samples to the
119 atmosphere, (ii) samples collected/stored in new materials (scoops, bags) and, (iii) sampling
120 conducted by one individual. A record was also kept of all plastic materials that came into contact
121 with the sample during collection and processing. One limitation was that no air contamination
122 check was included during sediment sampling onboard the vessel.

123

124 In the laboratory, sediments were defrosted, transferred into clean covered aluminium foil trays
125 and oven dried at 60°C for approximately 96 hours. Approximately 10 g of oven-dried sediment
126 was weighed and placed into a pre-cleaned glass jar. 105 mL of sodium tungstate dihydrate
127 (Na₂WO₄·2H₂O, 40 % w/v, density 1.4 g cm⁻³), as recommended by Frias et al. (2018) and Pagter
128 et al. (2018), was added to each glass jar, the mixture was shaken for approximately 1 minute and
129 the sediments were allowed to settle. From each sample jar, the overlying sodium tungstate
130 dihydrate solution was removed using a pipette and filtered under vacuum onto glass microfiber
131 paper (GF/C), Whatman 47 mm, pore size 1.2 µm, using a Buchner funnel and an Erlenmeyer
132 flask. Minimal volumes of ultrapure water (< 2 mL) were used to wash down the sides of the glass
133 jars with the sediments. Introducing water into the remaining extraction solution can lead to a
134 change in the density of the solution and thus this was minimised. Ultrapure water was also used

135 to wash the pipette and sides of the Buchner funnel. Filter papers for the samples were placed into
136 clean petri dishes and stored until analysis. Potential contamination was evaluated by using (i) air
137 contamination checks-clean petri dishes with filter paper (n = 2) were exposed to the air during
138 sample processing and, (ii) method blanks-jars devoid of sediment (n = 2) were processed in the
139 same manner as actual samples. Measures taken to prevent contamination in the laboratory
140 included (i) wearing lab coats and gloves during sample processing and, (ii) washing all glass jars
141 used during sample processing with a 6 % nitric acid solution and Ultra-pure water.

142
143 Filter papers were visually examined under a dissecting microscope (Olympus SZX10) equipped
144 with a polariser and camera (Q Imaging Retiga 2000R). Potential microplastics were isolated and
145 processed (photographed and length measurements taken) prior to transferring to a clean filter
146 paper in a labelled petri dish (Kanhai et al. 2017). Due to the difficulties that arise when handling
147 particles < 100 µm, such particles were automatically excluded for any analysis. All potential
148 microplastics and any plastic material that was in direct contact with the samples either during
149 sampling or laboratory processing were analysed by Fourier transform infrared (FT-IR)
150 spectroscopy on a Bruker Vertex 70 Infrared Spectrometer coupled to a Hyperion 1000 microscope
151 (Kanhai et al. 2017). Samples which produced spectra with a match < 60 % were automatically
152 rejected while those which produced a match of > 70 % were accepted. All spectra with matches
153 > 60 % were individually examined to ensure that there was clear evidence of peaks from the
154 sample corresponding to known peaks of standard polymers.

155

156 **3. Results**

157 In the present study, the following plastic materials made direct contact with the sediment samples
158 either during collection or processing (i) plastic film – low density polyethylene (LDPE), (ii) core
159 liner – polyvinyl chloride (PVC) or polycarbonate (PC), (iii) scraper - polypropylene (PP), (iv)
160 sediment collection scoop – polypropylene (PP) and, (v) sample bag – low density polyethylene
161 (LDPE). In the surficial sediment samples, no polyethylene particles were recovered. However, in
162 two instances, synthetic polymers from surficial sediments matched plastic materials used during
163 sample processing but were not eliminated since they were of different colours than the materials
164 used. This was so for 2 particles in sediment core 4 (single PVC fragment, different colour from
165 liner) and sediment core 7 (polypropylene fragment, different colour from collection

166 scoop/scrapper). To assess whether synthetic polymers were introduced during laboratory
167 processing of the samples, air contamination checks (ACs), (n = 2), and method blanks (MBs), (n
168 = 2), were included. No synthetic polymers were found in the air contamination blanks. However,
169 a total of three fibres were found in the two method blanks (MB1 – blue polyester fibre, 1.28 mm;
170 MB2 – blue polyester fibre, 0.49 mm and red polyester fibre, 0.53 mm). All samples were blank
171 corrected such that if any blue or red polyester fibres were found in the sediment samples, they
172 were removed from the final results.

173
174 Based on visual identification, fifteen particles from the sediment samples were isolated and
175 subjected to FTIR spectroscopy. Of these, four were natural cellulosic fibres. The remaining eleven
176 were identified as synthetic polymers with one macroplastic (> 5 mm) and ten microplastics (< 5
177 mm). After blank correction of the samples, there were a total of nine microplastics (<5 mm),
178 (Supplementary Table 2). Synthetic polymers detected in the sediments included polyester (n = 3),
179 polystyrene (n = 2), polyacrylonitrile (n = 1), polyamide (n = 1), polypropylene (n = 1) and
180 polyvinyl chloride (n = 1). Both fibres (n = 5) and fragments (n = 4) were present in the samples.
181 In terms of colour, most of the synthetic polymers were transparent (n = 5) with the remainder
182 black (n = 1), brown (n = 1), white (n = 1) and blue (n = 1). With respect to length, most (n = 5)
183 were < 1 mm, 3 were between 1 – 2 mm and 1 was > 2 mm. Of the surficial sediment samples
184 analysed from the Arctic Central Basin (ACB), 7 of the 11 samples contained between 1 – 2
185 synthetic polymers (Figure 1b).

186

187 **4. Discussion**

188 Elucidation of the transport and fate of microplastics in the marine environment is a critical step
189 towards assessing the threat that these contaminants potentially pose to organisms inhabiting
190 different compartments of an ecosystem. In the Arctic Central Basin (ACB), only a few studies
191 have reported on microplastic presence in the sea ice, biota and water column (Obbard et al. 2014;
192 Kuhn et al. 2018; Kanhai et al. 2018; Peeken et al. 2018). Based on these studies, the key
193 suggestions regarding microplastics in this oceanic basin are that (i) sea ice acts as a sink and
194 means of transport for microplastics, and (ii) the pervasiveness of microplastics in the various
195 water layers of the ACB indicates that there is vertical transport of microplastics out of surface
196 waters into deeper waters (Obbard et al. 2014; Kanhai et al. 2018; Peeken et al. 2018). In context,

197 the findings of the present study expand the knowledge base about microplastics in the Arctic
198 Ocean by providing preliminary information that suggests microplastics are present in surficial
199 sediments of the Arctic Central Basin and that within this oceanic basin the sediment compartment
200 is potentially acting as one of the sinks for microplastics. Microplastic presence on the seafloor of
201 the ACB lends credence to the suggestion that there is vertical transport of microplastics within
202 the water column. Laboratory and field studies have shown that marine organisms, such as
203 zooplankton, larvaceans and other pelagic filter feeders, which are capable of ingesting
204 microplastics and egesting them in their faecal pellets and discarded houses (as in the case of the
205 larvaceans), could contribute to the vertical flux of microplastics in the water column when their
206 waste products sink (Cole et al. 2016; Katija et al. 2017). The incorporation of microplastics into
207 marine aggregates and the biofouling of microplastics are other processes which may influence the
208 vertical transport of these particles in the water column (Long et al., 2015; Fazey and Ryan 2016).
209

210 The presence of microplastics in sediments of the Arctic Central Basin implies that interactions
211 between these particles and deep-sea organisms that inhabit or depend upon this environmental
212 phase is plausible. Although the Arctic Ocean has generally been regarded as oligotrophic, the fact
213 remains that marine organisms do inhabit its' deep-water environment with the most speciose
214 groups being arthropods, foraminiferans, annelids and nematodes (Bodil et al. 2011). Depending
215 on the foraging behaviours and feeding habits of deep-sea benthos in the ACB, the possibility
216 exists that some of them may be interacting with microplastics in the sediment phase. Recently,
217 Fang et al. (2018) reported that microplastics were discovered in 11 different benthic species that
218 were recovered from depths of 35 – 151 m in the Bering-Chukchi Sea shelves. Fibres were the
219 predominant type of microplastics found in the organisms with synthetic polymers including
220 polyamide, polyethylene, polyester and cellophane (Fang et al. 2018). Microplastics were also
221 discovered in 3 different phyla (Echinodermata, Arthropoda, Cnidaria) of deep sea organisms
222 recovered from depths of 334 – 1783 m in the equatorial mid-Atlantic and SW Indian Ocean
223 (Taylor et al. 2016). Although the presence of a contaminant in the marine environment does not
224 directly imply harm, laboratory experiments have indicated that benthic organisms exposed to
225 microplastics in sediments may be negatively impacted. For example, Wright et al. (2013) reported
226 that exposure of the deposit-feeding marine polychaete worm (*Arenicola marina*) to unplastified

227 polyvinyl chloride (UPVC) led to a depletion in energy reserves of the worms which could have
228 been caused by reduced feeding, longer gut residence time of ingested matter and inflammation.

229
230 The present study confirmed via FT-IR spectroscopy that polyesters were recovered from surficial
231 sediments of the ACB. Such findings are corroborated by previous studies which investigated other
232 environmental phases in this oceanic basin. Obbard et al. (2014) reported that of the synthetic
233 polymers found in sea ice, the majority were polyester (21 %). Kanhai et al. (2018) similarly found
234 that of the synthetic particles present in the sub-surface waters, polyesters (74 – 78 %) were also
235 predominant. Upon melting, sea ice can act as a local source of microplastics to the water column
236 (Obbard et al. 2014; Peeken et al. 2018). Synthetic polymers that are present in surface waters of
237 this oceanic basin could then be subject to vertical transport, persist in the water column as
238 evidenced by Kanhai et al. (2018) and at some stage a fraction of these particles could end up in
239 the sediment phase. Of interest is the fact that the present study found low density polymers such
240 as polypropylene and polystyrene fragments in the sediments of the ACB. Based on the inherent
241 densities of the virgin resins, such particles are unlikely candidates for the sediment phase in that
242 they are positively buoyant and are expected to float. However, this suggests that there are
243 mechanisms operating within the ACB that could be affecting the density of these particles and in
244 effect causing them to end up in the sediment phase. Long et al. (2015) showed that under
245 laboratory conditions marine aggregates of various algal species (*Chaetoceros neogracile*,
246 *Rhodomonas salina*) were capable of incorporating and concentrating polystyrene microbeads
247 which in turn led to an increase in their sinking rates. Such mechanisms can potentially explain
248 the presence of low-density polymers in surficial sediments of the ACB. Of note is the fact that
249 the present study is not the first to report the presence of low density polymers in deep sea
250 sediments since polyethylene and polypropylene particles were found in surficial sediments from
251 the Fram Strait (Bergmann et al. 2017).

252
253 Within the last decade, deep-sea sediments were for the first time identified as a potential sink for
254 microplastics with four studies reporting on the issue in various oceanic basins (Supplementary
255 Table 3). Comparison between these studies is particularly challenging and not straightforward
256 due to the fact that each used different sampling equipment, extraction techniques and reported
257 microplastic abundance/concentration in different units (Supplementary Table 3). Microplastic

258 abundance in surficial sediments of the ACB was estimated to range between 0 – 200 microplastics
259 kg⁻¹ dry sediment based on the findings of the present study. However, it is unlikely that these
260 estimates are reflective of the situation in the ACB since (i) the equipment used for sample retrieval
261 (gravity and piston corers) may have led to the collection of disturbed surficial sediment samples,
262 (ii) low sample volumes (~ 10 g per site) were used to assess microplastic abundance, (iii) the
263 density of the extraction solution was only 1.4 g cm⁻³ and thus could have excluded high density
264 polymers, (iv) replicate sediment samples per site was not possible, (v) particles < 100 µm were
265 excluded by virtue of the procedure used to identify/isolate potential microplastics. During the
266 AO16 expedition, gravity and piston corers were used to retrieve sediments from several metres
267 in depth from the ACB. Among the corers, gravity and piston corers are not guaranteed to retrieve
268 undisturbed surficial sediment samples due to the shock wave that they generate during descent
269 (Gallmetzer et al. 2016). It is therefore likely that any shock waves generated by the corers used
270 in the present study may have triggered a resuspension of surficial material (sediments and
271 microplastics) into the water column leading to an overall reduction and subsequent
272 underestimation of microplastic abundance in the samples. When sampling surficial marine
273 sediments, equipment such as box and multi-corers may be more suitable for the recovery of
274 undisturbed surficial sediment samples (Georgiopoulou 2018). Box corers were recommended by
275 Frias et al. (2018) due to (i) the minimal impact they have on surface deformation of sediments
276 and, (ii) their ability to maintain sediment integrity during sampling.

277
278 Furthermore, due to the heterogenous nature of sediments, it is unlikely that the low sample
279 volumes (~ 10 g of sediment) used in the study were reflective of the situation at the respective
280 sites. Future studies should ensure that replicate samples are collected per site. Multi-corers may
281 be particularly useful since they can facilitate the collection of replicate samples in a single
282 deployment. When density separation is used to extract microplastics from sediment samples, the
283 density of the extraction solution is important in determining which synthetic polymers are
284 extracted from the samples. Although sodium tungstate dihydrate (density 1.4 g cm⁻³) was used in
285 the present study based on a safety-price index assessment (i.e. cost and health hazard), the density
286 of the solution could have led to the exclusion of some high-density polymers (Frias et al. 2018).
287 Loder and Gerdts (2015) recommended the use of zinc chloride based on its cost effectiveness and
288 its higher density of 1.8 g cm⁻³. However, the health hazard is high for this particular extraction

289 solution (Frias et al. 2018). Finally, the methods employed by investigators for the isolation and
290 identification of microplastics influences the final reported microplastic abundance. In the present
291 study, particles < 100 µm were automatically excluded from analysis. However, it must be noted
292 that at the Atlantic gateway to the Arctic Ocean i.e. the Fram Strait, Bergmann et al. (2017)
293 reported that the majority (80 %) of microplastics in surficial sediments from that area were < 25
294 µm. Bergmann et al. (2017) used a combination of ATR-FTIR spectroscopy as well as a µFTIR
295 microscope equipped with a focal plane array detector to detect microplastics. It is therefore likely
296 that if similar analytical techniques were employed to analyse the surficial sediment samples of
297 the present study, higher microplastic abundances may have been reported, especially in the cases
298 where zero microplastics were reported in certain samples.

299
300 Another limitation of the present study is the non-inclusion of an air contamination check during
301 sampling onboard the vessel. Such a check would have been necessary to rule out airborne
302 contamination during sampling. Since this was not done, the possibility exists that one or more of
303 the particles reported as present in the surficial sediments of the ACB could have been introduced
304 into the samples as a result of airborne contamination. The findings of the present study should
305 therefore be regarded as preliminary and be used as a justification for future studies which can
306 provide more comprehensive assessments of microplastics in deep-sea sediments of the Arctic
307 Central Basin.

308

309 **5.0 Conclusion**

310 To our knowledge, this is the first study to present preliminary information regarding microplastics
311 in surficial sediments of the Arctic Central Basin (ACB). The potential discovery of these particles
312 in the sediment phase of this seemingly remote oceanic basin emphasizes the pervasiveness of
313 microplastics in the marine environment. The possible presence of microplastics, specifically low-
314 density polymers such as polypropylene (PP) and polystyrene (PS), in the sediment phase of the
315 ACB suggests that there are mechanisms operating within this oceanic basin that are potentially
316 affecting the density of microplastics and that are potentially driving the vertical transport of these
317 particles through the water column. Microplastics that are present in sediments of the ACB are
318 likely to interact with organisms inhabiting or depending upon this environmental phase. At
319 present, whether those interactions are occurring with benthic organisms within the ACB and the

320 consequences of those interactions to individual organisms and the ecosystem services that they
321 perform remains uncertain. Due to the numerous limitations of the present study, the findings
322 should not be taken as conclusive regarding the status of microplastics in the surficial sediments
323 of the ACB but instead be used as a foundation for future work seeking to quantify microplastic
324 abundance, distribution and composition in surficial sediments of the Arctic Ocean.

325

326 **Acknowledgements**

327 The authors acknowledge the invaluable support of the staff of the Swedish Polar Research
328 Secretariat (especially Jeanette Axelsson, Robert Holden, Lars Lehnert, Asa Lindgren, Axel
329 Meiton and Per Salo) and the crew of icebreaker Oden with the Arctic Ocean 2016 expedition. The
330 expert guidance of Mr. Andrew Tonkin (University of Plymouth) during FT-IR analyses is also
331 acknowledged. The first author also acknowledges the support of the coring technicians (Draupnir
332 Einarsson, Markus Karasti), fellow early career scientists (especially those of the Sediment Work
333 Package: Grace Shephard, Luz María Ramirez, Steffen Wiers) and other researchers (especially
334 Asa Johannisson) during the expedition.

335

336 **Funding**

337 Sampling in the Arctic Ocean was funded by the Swedish Polar Research Secretariat (SPRS) under
338 the Early Career Scientist (ECS) Programme in which the first author was a participant. This work
339 was also co-funded through a MARES Grant. MARES is a Joint Doctorate programme selected
340 under Erasmus Mundus and coordinated by Ghent University (FPA 2011-0016). The funders had
341 no role in study design, data collection, analysis and interpretation, decision to publish, or
342 preparation of the manuscript.

343

344 **References**

- 345 Bergmann, M., Wirzberger, V., Krumpen, T., Lorenz, C., Primpke, S., Tekman, M.B., Gerdts, G.,
346 2017. High Quantities of Microplastic in Arctic Deep-Sea Sediments from the
347 HAUSGARTEN Observatory. *Environmental Science & Technology* 51 (19), 11000-
348 11010. <https://doi.org/10.1021/acs.est.7b03331>
- 349 Bodil, B.A., Ambrose, W.G., Bergmann, M., Clough, L.M., Gebruk, A.V., Hasemann, C., Iken,
350 K., Klages, M., MacDonald, I.R., Renaud, P.E., Schewe, I., Soltwedel, T., Włodarska-

351 Kowalczyk, M., 2011. Diversity of the arctic deep-sea benthos. *Marine Biodiversity* 41 (1),
352 87-107. <https://doi.org/10.1007/s12526-010-0078-4>

353 Cole, M., Lindeque, P.K., Fileman, E., Clark, J., Lewis, C., Halsband, C., Galloway, T.S., 2016.
354 Microplastics Alter the Properties and Sinking Rates of Zooplankton Faecal Pellets.
355 *Environmental Science & Technology* 50 (6), 3239-3246.
356 <https://doi.org/10.1021/acs.est.5b05905>

357 Cózar, A., Echevarria, F., Gonzalez-Gordillo, J.I., Irigoien, X., Ubeda, B., Hernandez-Leon, S.,
358 Palma, A.T., Navarro, S., Garcia-de-Lomas, J., Ruiz, A., Fernandez-de-Puelles, M.L.,
359 Duarte, C.M., 2014. Plastic debris in the open ocean. *Proceedings of the National Academy*
360 *of Sciences* 111 (28), 10239-10244. <https://doi.org/10.1073/pnas.1314705111>

361 Cózar, A., Marti, E., Duarte, C.M., Garcia-de-Lomas, J., van Sebille, E., Ballatore, T.J., Eguiluz,
362 V.M., Gonzalez-Gordillo, J.I., Pedrotti, M.L., Echevarria, F., Trouble, R., Irigoien, X.,
363 2017. The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of
364 the Thermohaline Circulation. *Science Advances* 3 (e1600582).
365 <https://doi.org/10.1126/sciadv.1600582>

366 Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F.,
367 Ryan, P.G., Reisser, J., 2014. Plastic Pollution in the World's Oceans: More than 5 Trillion
368 Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS ONE* 9 (12), e111913.
369 <https://doi.org/10.1371/journal.pone.0111913>

370 Fang, C., Zheng, R., Zhang, Y., Hong, F., Mu, J., Chen, M., Song, P., Lin, L., Lin, H., Le, F., Bo,
371 J., 2018. Microplastic contamination in benthic organisms from the Arctic and sub-Arctic
372 regions. *Chemosphere* 209, 298-306. <https://doi.org/10.1016/j.chemosphere.2018.06.101>

373 Fazey, F.M.C., Ryan, P.G., 2016. Biofouling on buoyant marine plastics: An experimental study
374 into the effect of size on surface longevity. *Environmental Pollution* 210, 354-360.
375 <https://doi.org/10.1016/j.envpol.2016.01.026>

376 Fischer, V., Elsner, N.O., Brenke, N., Schwabe, E., Brandt, A., 2015. Plastic pollution of the Kuril–
377 Kamchatka Trench area (NW pacific). *Deep Sea Research Part II: Topical Studies in*
378 *Oceanography* 111, 399-405. <https://doi.org/10.1016/j.dsr2.2014.08.012>

379 Frias, J., Pagter, E., Nash, R., O'Connor, I., Carretero, O., Filgueiras, A., Viñas, L., Gago, J.,
380 Antunes, J., Bessa, F., Sobral, P., Goruppi, A., Tirelli, V., Pedrotti, M.L., Suaria, G., Aliani,
381 S., Lopes, C., Raimundo, J., Caetano, M., Palazzo, L., Lucia, G.A.d., Camedda, A.,

382 Muniategui, S., Grueiro, G., Fernandez, V., Andrade, J., Dris, R., Laforsch, C., Scholz-
383 Böttcher, B.M., Gerds, G., 2018. Standardised protocol for monitoring microplastics in
384 sediments. JPI-Oceans BASEMAN project.
385 <https://doi.org/10.13140/RG.2.2.36256.89601/1>

386 Gallmetzer, I., Haselmair, A., Stachowitsch, M., Zuschin, M., 2016. An innovative piston corer
387 for large-volume sediment samples. *Limnology and Oceanography: Methods* 14 (11), 698-
388 717. <https://doi.org/10.1002/lom3.10124>

389 Georgiopoulou, A., 2018. Seafloor Sediment and Rock Sampling. In: Micallef, A., Krastel, S.,
390 Savini, A. (Eds.), *Submarine Geomorphology*. Springer International Publishing, Cham,
391 pp. 75-92. https://doi.org/10.1007/978-3-319-57852-1_6

392 Jakobsson, M., Grantz, A., Kristoffersen, Y., Macnab, R., MacDonald, R.W., Sakshaug, E., Stein,
393 R., Jokat, W., 2004. The Arctic Ocean: Boundary Conditions and Background Information.
394 In: Stein, R., MacDonald, R.W. (Eds.), *The Organic Carbon Cycle in the Arctic Ocean*.
395 Springer, Berlin. https://doi.org/10.1007/978-3-642-18912-8_1

396 Kanhai, L.D.K., Officer, R., Lyashevskaya, O., Thompson, R.C., O'Connor, I., 2017. Microplastic
397 abundance, distribution and composition along a latitudinal gradient in the Atlantic Ocean.
398 *Marine Pollution Bulletin* 115 (1-2), 307-314.
399 <https://doi.org/10.1016/j.marpolbul.2016.12.025>

400 Kanhai, L.D.K., Gårdfeldt, K., Lyashevskaya, O., Hassellöv, M., Thompson, R.C., O'Connor, I.,
401 2018. Microplastics in sub-surface waters of the Arctic Central Basin. *Marine Pollution*
402 *Bulletin* 130, 8-18. <https://doi.org/10.1016/j.marpolbul.2018.03.011>

403 Katija, K., Choy, C.A., Sherlock, R.E., Sherman, A.D., Robison, B.H., 2017. From the surface to
404 the seafloor: How giant larvaceans transport microplastics into the deep sea. *Science*
405 *Advances* 3 (8), e1700715. <https://doi.org/10.1126/sciadv.1700715>

406 Kuhn, S., Schaafsma, F.L., van Werven, B., Flores, H., Bergmann, M., Egelkraut-Holtus, M.,
407 Tekman, M.B., van Franeker, J.A., 2018. Plastic ingestion by juvenile polar cod
408 (*Boreogadus saida*) in the Arctic Ocean. *Polar Biology*, 1-10.
409 <https://doi.org/10.1007/s00300-018-2283-8>

410 Löder, M.G.J., Gerds, G., 2015. Methodology Used for the Detection and Identification of
411 Microplastics—A Critical Appraisal. In: Bergmann, M., Gutow, L., Klages, M. (Eds.),

412 Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 201-227.
413 https://doi.org/10.1007/978-3-319-16510-3_8

414 Long, M., Moriceau, B.I., Gallinari, M., Lambert, C., Huvet, A., Raffray, J., Soudant, P., 2015.
415 Interactions between microplastics and phytoplankton aggregates: Impact on their
416 respective fates. *Marine Chemistry* 175, 39-46.
417 <https://doi.org/10.1016/j.marchem.2015.04.003>

418 Lusher, A.L., Tirelli, V., O'Connor, I., Officer, R., 2015. Microplastics in Arctic polar waters: the
419 first reported values of particles in surface and sub-surface samples. *Scientific Reports* 5,
420 1-9. <https://doi.org/10.1038/srep14947>

421 Mallory, M.L., 2008. Marine plastic debris in northern fulmars from the Canadian high Arctic.
422 *Marine Pollution Bulletin* 56 (8), 1501-1504.
423 <https://doi.org/10.1016/j.marpolbul.2008.04.017>

424 Mu, J., Qu, L., Jin, F., Zhang, S., Fang, C., Ma, X., Zhang, W., Huo, C., Cong, Y., Wang, J., 2019.
425 Abundance and distribution of microplastics in the surface sediments from the northern
426 Bering and Chukchi Seas. *Environmental Pollution* 245, 122-130.
427 <https://doi.org/10.1016/j.envpol.2018.10.097>

428 Obbard, R.W., Sadri, S., Wong, Y.Q., Khitun, A.A., Baker, I., Thompson, R.C.C.E.F., 2014.
429 Global warming releases microplastic legacy frozen in Arctic Sea ice. *Earth's Future* 2 (6),
430 315-320. <https://doi.org/10.1002/2014ef000240>

431 Pagter, E., Frias, J., Nash, R., 2018. Microplastics in Galway Bay: A comparison of sampling and
432 separation methods. *Marine Pollution Bulletin* 135, 932-940.
433 <https://doi.org/10.1016/j.marpolbul.2018.08.013>

434 Peeken, I., Primpke, S., Beyer, B., Gütermann, J., Katlein, C., Krumpfen, T., Bergmann, M.,
435 Hehemann, L., Gerds, G., 2018. Arctic sea ice is an important temporal sink and means of
436 transport for microplastic. *Nature Communications* 9 (1), 1505.
437 <https://doi.org/10.1038/s41467-018-03825-5>

438 Provencher, J.F., Gaston, A.J., Mallory, M.L., O'hara, P.D., Gilchrist, H.G., 2012. Ingested plastic
439 in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic.
440 *Marine Pollution Bulletin* 60 (9), 1406-1411.
441 <https://doi.org/10.1016/j.marpolbul.2010.05.017>

442 R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for
443 Statistical Computing, Vienna, Austria. <https://www.R-project.org/>

444 Schlitzer, R., 2017. Ocean Data View. <https://odv.awi.de>

445 Taylor, M.L., Gwinnett, C., Robinson, L.F., Woodall, L.C., 2016. Plastic microfibre ingestion by
446 deep-sea organisms. *Scientific Reports* 6, 33997. <https://doi.org/10.1038/srep33997>

447 Tekman, M.B., Krumpen, T., Bergmann, M., 2017. Marine litter on deep Arctic seafloor continues
448 to increase and spreads to the North at the HAUSGARTEN observatory. *Deep Sea*
449 *Research Part 1: Oceanographic Research Papers* 120, 88-99.
450 <http://dx.doi.org/10.1016/j.dsr.2016.12.011>

451 Van Cauwenberghe, L., Vanreusel, A., Mees, J., Janssen, C.R., 2013. Microplastic pollution in
452 deep-sea sediments. *Environmental Pollution* 182, 495-499.
453 <http://dx.doi.org/10.1016/j.envpol.2013.08.013>

454 Van Sebille, E., England, M.H., Froyland, G., 2012. Origin, dynamics and evolution of ocean
455 garbage patches from observed surface drifters. *Environmental Research Letters* 7 (4), 1-
456 6. <https://doi.org/10.1088/1748-9326/7/4/044040>

457 Woodall, L.C., Sanchez-Vidal, A., Canals, M., Paterson, G.L.J., Coppock, R., Sleight, V., Calafat,
458 A., Rogers, A.D., Narayanaswamy, B.E., Thompson, R.C., 2014. The deep sea is a major
459 sink for microplastic debris. *Royal Society Open Science* 1 (4).
460 <https://doi.org/10.1098/rsos.140317>

461 Wright, S.L., Rowe, D., Thompson, R.C., Galloway, T.S., 2013. Microplastic ingestion decreases
462 energy reserves in marine worms. *Current Biology* 23 (23), R1031-R1033.
463 <http://dx.doi.org/10.1016/j.cub.2013.10.068>

464 Zarfl, C., Matthies, M., 2010. Are marine plastic particles transport vectors for organic pollutants
465 to the Arctic? *Marine Pollution Bulletin* 60 (10), 1810-1814.
466 <http://dx.doi.org/10.1016/j.marpolbul.2010.05.026>

Supplementary Table 1: Site-specific information for sediment cores sampled for microplastics in the Arctic Central Basin

Sample No. ^a	Core ID	Latitude	Longitude	Location in the ACB	Water Depth (m)	Core Type ^b
1	AO16-1-GC1	80.5532	8.0520	Yermak Plateau	855	GC
2	AO16-2-PC1	88.5022	-6.6195	Amundsen Basin	4353	PC
3	AO16-3-TWC1	89.2530	-66.6097	Foot of Lomonosov Ridge	3777	TWC
4	AO16-4-TWC1	88.5290	-128.5048	Marvin Spur	3936	TWC
5	AO16-5-TWC1	89.0780	-130.5470	Crest of Lomonosov Ridge	1253	TWC
6	AO16-7-PC1	88.6332	-121.4477	Marvin Spur	3941	PC
7	AO16-8-GC1	86.7795	-140.6433	Alpha Ridge	2620	GC
8	AO16-9-TWC1	85.9557	-148.3258	Alpha Ridge	2212	TWC
9	AO16-10-TWC1	82.3980	-141.2450	Nautilus Basin	2872	TWC
10	AO16-11-TWC1	86.0993	173.1877	Makarov Basin	3066	TWC
11	AO16-12-TWC1	87.8577	136.9875	Crest of Lomonosov Ridge	1269	TWC

^aSample numbers correspond to those on Figure 1a; ^bGC (Gravity core); PC (Piston core); TWC (Trigger weight core)

Supplementary Information related to particle size and organic carbon content analysis

Method: For particle size analysis, approximately 0.1 g of wet sediment from each sediment core was transferred to a test tube. To this, 3 mL of sodium metaphosphate solution (10%) was added and the total volume brought to 10 mL using de-ionized water. The contents of the tube were stirred, ultrasonicated for approximately 30 seconds to facilitate disaggregation and then transferred to the Hydro LV wet dispersion unit of a Mastersizer 3000 laser diffraction particle size analyser (Malvern Instruments, UK). De-ionized water was used to bring the final volume in the wet dispersion unit to 600 mL prior to analysis. The particle size of surficial sediments from each core was based on the analysis of three sub-samples. Following Pagter et al. (2018), approximately 3 g of dried sediment (105 °C, 4 h) from each sample was placed into a furnace at 450 °C for 6 hours in order to estimate the organic content of the sediment samples based on loss on ignition. Grain size composition of the surficial sediment data was conducted using Gradistat Version 8 (Blott 2010).

Results: Regarding the particle size composition of the sediments, all sampled sites had a predominance of fine-grained sediments where the percentage of silt (59 – 87 %) > clay (10 - 24 %) > sand (1 – 23 %) > gravel (0 – 0.2 %), (Supplementary Table 1). Organic content of the surficial sediment samples ranged between 2.3 – 4.6 % (Supplementary Table 1).

Reference:

Blott, S., 2010. Gradistat Version 8: A grain size distribution and statistics package for the analysis of unconsolidated sediments by sieving or laser granulometer. Kenneth Pye Associates Limited, Berkshire, UK.

Supplementary Table 2: Synthetic polymer composition and grain sizes of surficial sediments in the Arctic Central Basin

	Sample Number										
	1	2	3	4	5	6	7	8	9	10	11
Grain size composition (%)											
Total Gravel (%)	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.1	0.0
Total Sand (%)	3.3	5.2	1.2	7.5	12.4	15.2	17.5	16.4	22.6	10.2	7.5
Total Silt (%)	86.9	73.6	76.4	68.4	70.5	65.6	63.4	63.0	59.3	69.8	73.7
Total Clay (%)	9.8	21.2	22.5	24.1	17.1	19.2	18.9	20.5	18.0	19.8	18.7
Organic content (%)											
	4.6	4.0	4.4	3.5	3.3	2.6	3.4	3.6	2.6	2.3	2.8
Polymer Type (n)											
Polyacrylonitrile (PAN)			1								
Polyamide (PA)					1						
Polyester (PES)		2									1
Polypropylene (PP)							1				
Polystyrene (PS)							1	1			
Polyvinyl chloride (PVC)				1							
Total number of synthetic polymers	0	2	1	1	1	0	2	1	0	0	1
Size (mm); Type (Fi-fibre; Fr-fragment) of microplastics		1.84 (Fi) 1.38 (Fi)	0.47 (Fi)	0.91 (Fr)	3.58 (Fi)		0.88 (Fr) 0.54 (Fr)	0.45 (Fr)			1.03 (Fr)
Microplastic concentration											
Mass of dry sediment used (g)	10.02	10.12	7.86	9.83	10.20	10.89	9.31	10.09	10.07	10.36	4.54
Microplastic concentration (items kg ⁻¹)	0	198	127	102	98	0	215	99	99	97	220

Supplementary Table 3: Microplastics in deep sea sediments of various oceanic basins

Location	Depth (m)	Sampling Equipment	Extraction Method	Microplastic abundance	Synthetic polymers	Study
Porcupine Abyssal Plain Nile Deep Sea Fan Atlantic Sector of the Southern Ocean	1176 – 4843	Multicorer	Density flotation, NaI (1.6 g cm ⁻³)	0.5 particles cm ⁻³ (average, n = 11) 1 particle cm ⁻³ (max)	No data	Van Cauwenberghe et al. (2013)
Subpolar North Atlantic Ocean NE Atlantic Ocean Mediterranean Sea SW Indian Ocean	300 – 3500	Megacorers Boxcorers	Density flotation, NaCl, Ludox-TM 40 extraction	1.4 - 40 pieces per 50 ml (mean ± s.e., 13.4 ± 3.5)	PA, PES, Acrylic Rayon	Woodall et al. (2014)
Kuril-Kamchatka Trench, NW Pacific	4869 - 5768	Box corer	Sieve-washing of sediments	60 - 2020 pieces m ⁻²	No data	Fischer et al. (2015)
HAUSGARTEN observatory, Fram Strait	2340 - 5570	Multiple corer	Density separation, zinc chloride (1.8 g cm ⁻³)	42 – 6595 microplastics kg ⁻¹ dry sediment	18 polymer types detected. Majority: PE, PA, PP	Bergmann et al. (2017)
Arctic Central Basin	855 - 4353	Gravity and piston corer	Density separation, sodium tungstate dihydrate (1.4 g cm ⁻³)	0 - 200 microplastics kg ⁻¹ dry sediment	PA, PAN, PES, PP, PS, PVC	This study

PA-Polyamide, PAN-Polyacrylonitrile, PES-Polyester, PP-Polypropylene, PS-Polystyrene, PVC-Polyvinyl chloride