

1 **Benthic foraminiferal assemblages and environmental drivers along** 2 **the Kveithola Trough (NW Barents Sea)**

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5

6 **Abstract**

7 We report the living benthic foraminiferal density, biodiversity, and vertical distribution
8 related to the environmental features from the shallow Kveithola Trough (NW Barents
9 Sea). Based on the CTG technique that we confirm is a very effective way to
10 distinguish living from dead foraminifera, we document the faunal assemblage
11 variability along the transect. The outer shelf shows a diverse benthic foraminiferal
12 assemblage suggesting an oxygenated and oligotrophic environment. The central part
13 appears a disturbed area due to rapid circulation changes and organic matter burial in
14 sediments where opportunistic foraminifera colonize only the first centimeters. Instead,
15 the inner part appears as a stressed environment where species associated with
16 organic-rich sediment and oxygen-depleted environments dominate the living
17 assemblage. In all sites, we notice the presence of delicate monothalamous species.
18 The peculiar geomorphological and environmental conditions of this area and the high
19 regional primary and secondary production are key drivers of foraminiferal
20 assemblage distribution.

21 Keywords: Arctic, benthic foraminifera, Cell Tracker Green, oceanography,
22 geochemistry, sedimentology

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42 **1.Introduction**

43 Foraminifera are unicellular eukaryotes that occur ubiquitously in all the world oceans
44 and marine habitats, including both pelagic and benthic environments. Of these,
45 benthic foraminifera are an important component of marine systems and may even
46 account for 50% of eukaryotic biomass (Gooday et al., 1992). These organisms are
47 excellent indicators for assessing the exported productivity to the ocean floor (van der
48 Zwaan et al., 1999) for energy transfer at the higher trophic levels (Fontanier et al.,
49 2006; Langezaal et al., 2006) and for the recycling of the organic matter decomposing
50 in the sediments or in the bottom waters (Gooday et al., 1992; Cusson and Bourget,
51 2005). Foraminifera have a short life cycle and react rather quickly to environmental
52 changes. In fact, the physico-chemical properties of water-masses and sediment types
53 including the temperature, pH, oxygenation, grain size and organic carbon content,
54 and the characteristics of bottom currents, (Gupta, 1999; Fontanier et al., 2002;
55 Murray, 2006; Martins et al., 2016) mostly control the distribution, abundance and
56 diversity of benthic foraminifera. For these reasons, the study of foraminifera
57 represents a powerful tool in the reconstruction of (paleo)environmental
58 characteristics, and in the evaluation of the effects of pollutant and other
59 anthropogenic impacts on marine environments (du Châtelet and Debenay, 2010;
60 Frontalini and Coccioni, 2011; Martins et al., 2016). An essential issue in the biological
61 and ecological studies is investigating the foraminiferal vitality by distinguishing
62 between the living and dead foraminifera. Over recent years, researchers used
63 different techniques to identify live cells, each one having a different degree of
64 accuracy and, both, advantages and disadvantages (Bernhard et al., 1995; Bernhard,
65 2000; Bernhard, 2006; De Nooijer et al., 2006; Borrelli et al., 2011; Caille et al., 2015;
66 Mojtahid et al., 2016). The present study was inspired by the paper of Bernhard et al.
67 (2006) that compared Rose bengal (RB) and Cell Tracker Green (CTG) stains. They
68 investigated deep-water (220-920 m depth) benthic foraminifera and demonstrated
69 that for quantifying living meiofauna in hypoxic/anoxic settings. CTG is a more
70 accurate method than the widely used RB staining, which over-estimated the
71 abundance of living specimens by 47%. Based on these considerations, the main
72 objectives of the present paper are: 1) to describe, for the first time, the foraminiferal
73 assemblage of the Kveithola glacial Trough located in the NW Barents Sea (Arctic),
74 comparing and discussing the use of RB and CTG on the foraminiferal fauna in which

75 organic-rich sediments suggest the existence of oxygen-depleted environmental
76 conditions; 2) compare and discuss the results regarding the vitality of foraminifera
77 presented in this paper in relation to the physico-chemical oceanographic patterns and
78 trophic status in the Kveithola Trough to get an integrated, comprehensive view of the
79 environment at the time of sampling.

80 **1.1. Study Area- Sedimentology and Oceanography**

81 The Kveithola Trough (Figure 1) is an abrupt and narrow glacial sedimentary system
82 located in the NW Barents Sea. It is *ca.* 100 km long extending in an E-W direction,
83 and less than 13 km wide with a depth range of 200-400 m along its major axis (Rüther
84 et al., 2012). The sea floor presents a series of E–W trending mega-scale glacial
85 lineations associated with a fast-flowing ice stream that crossed the trough during the
86 Last Glacial Maximum, and transverse, N-S oriented Grounding-Zone Wedges (GZW)
87 that were generated during the episodic retreat of the last glacial ice sheet during the
88 last glacial termination, giving rise to a stepped bathymetric axial profile of the trough
89 (Rebesco et al., 2011; Bjarnadóttir et al., 2013). The inner part of the trough hosts a
90 complex sediment drift characterised by two main depocentres (main and minor drifts;
91 Rebesco et al., 2016), with internal acoustic reflectors on the sub-bottom record
92 indicating persistent bottom currents that were active in the area since at least 13 cal
93 ka BP (Bjarnadóttir et al., 2013; Rebesco et al., 2016). Further, the trough is
94 intersected in a N-S direction by the Hornsund and Knølegga fault systems, the latter
95 of which being responsible for an elongated bathymetric depression indicated as the
96 “northern channel” (Hanebuth et al., 2013; Zecchin et al., 2016) that conducts dense
97 bottom currents delivering sediments towards the main drift (Fohrmann et al., 1998;
98 Lucchi et al., 2016; Rebesco et al., 2016; Lantzsich et al., 2017).

99 The Kveithola Trough is influenced by cold and relatively low salinity waters (Eastern
100 Spitsbergen Current, ESC), coming from the Arctic Ocean (Aagaard et al., 1985;
101 Aagaard, 1989; Loeng, 1991; Orvik and Niiler, 2002) and by the warmer and saltier
102 Atlantic Water (AW) (Figure 1). The latter is transported by the West Spitsbergen
103 Current (WSC), a branch of the North Atlantic Current (NAC), which brings heat and
104 salt to the high latitudes following bathymetric constraints and exerting a substantial
105 control on the climate of the region and sea-ice extension (Aagaard et al., 1975;
106 Aagaard et al., 1981; Aagaard, 1989; Vinje and Kvambekk, 1991; Loeng et al., 1997;

107 Maslowski et al., 2004; R  ther et al., 2012; Smedsrud et al., 2013). The Kveithola
108 Trough is seasonally influenced by the presence of sea-ice representing the
109 southernmost limit of the maximum sea-ice winter extension within the northwest
110 Barents Sea. Long-term climate trends, and the effects of large-scale climatic patterns
111 such as the Pacific Decadal Oscillation, the North Pacific Gyre Oscillation, and the
112 North Atlantic Oscillation-like pressure conditions (e.g., Koenigk et al., 2009; Yang et
113 al., 2020) are the main forcing mechanisms driving the sea-ice extent in the Barents
114 Sea. This area suffers from a substantial interannual variability as well as a
115 progressive, long-term reduction of sea-ice (Onarheim et al., 2017). The Kveithola
116 Trough is a peculiar area characterised by a large portion of relatively shallow seabed,
117 where the water column is strongly affected by the co-presence and interplay of AW
118 and Arctic water masses, seasonal influence of sea-ice melting waters, and
119 atmospheric processes able to induce local water mass mixing and enhance a strong
120 spatial and temporal variability of the thermohaline properties. Further, the bathymetric
121 characteristics (abrupt narrow trough) are responsible for an amplification of the local
122 impact of the tidal currents on the oceanographic patterns. Moreover, it is similar to
123 other Barents Sea shallow areas, where high nutrient rates reach the benthic
124 community and high regional primary and secondary production exist (Piepenburg and
125 Schmid, 1996; Piepenburg and Schmid, 1997; Grebmeier et al., 2006). Considering
126 the foraminiferal assemblages, some studies mapped the most abundant foraminifera
127 species (RB stained) from selected sites in the superficial sediment of the Barents Sea
128 (Saher et al., 2009; 2012). These reveal a shift toward warm temperature tolerant
129 species and, therefore, reflect a change in the climatic and oceanographic conditions.
130 We reported and added a close up on a reduced area, using a different labelled
131 methodology.

132 **2. Materials and Methods**

133 Sediment samples and oceanographic data were collected during the Eurofleets2-
134 BURSTER cruise onboard the German icebreaker RV Polarstern (Expedition PS99-
135 1a; June 13–23, 2016, Lucchi et al., 2016).

136 **2.1. Oceanographic data set**

137 **2.1.1. Thermohaline data**

138 Pressure (dbar), temperature (T, °C), salinity (S, PSU), dissolved oxygen (DO, ml l⁻¹),
139 and light beam transmission (BT, %, as indicator of water transparency) were recorded
140 throughout the water column using a SeaBird 911-plus CTD (Conductivity-
141 Temperature-Depth) probe mounted on the SBE 32 Carousel Water Sampler
142 (Rosette) equipped with 24 Niskin Bottles (12-litre capacity), approaching the
143 maximum depths 5-7 m above the seabed. High frequency (24 Hz) data were
144 processed, quality checked, and averaged every one dbar to obtain the final vertical
145 profiles. Overall, accuracies are within ±0.002°C for T, ±0.005 for S, and 2% of
146 saturation for DO. The DO concentration was also determined in parallel on water
147 samples taken at discrete depths from the Niskin bottles using the Winkler method
148 (Carpenter, 1965).

149 Potential temperature (θ) and potential density anomaly (σ_θ , kg m⁻³, referred to 0 dbar)
150 were calculated from each vertical profile using the toolbox TEOS-10 ([http://www.teos-](http://www.teos-10.org/software.htm)
151 [10.org/software.htm](http://www.teos-10.org/software.htm)). Some data are plotted using Ocean Data View (ODV; Schlitzer,
152 2020).

153 **2.1.2. Horizontal currents**

154 Speed and direction of the horizontal component of the oceanic currents were
155 measured by a vessel mounted Acoustic Doppler Current Profiler (vmADCP, Teledyne
156 RDI 150 kHz Ocean Surveyor configured in 'Narrowband' mode) along the ship track
157 with a time interval of 20 minutes. Vertical profiles were recorded within 80 cells with
158 4 m size, obtaining data from approximately 20 m to 340 m depth. However, there was
159 no data within a 40-50 m thick layer above the seafloor. Considering that in the
160 Kveithola Trough the maximum bottom depth is about 370 m, the bottom tracking

161 mode was used for the vmADCP to permit a higher accuracy on the ship velocity
162 measurements and, therefore, a better quality of the ocean current data. At the sites
163 where the ship remained on station for several hours, we calculated an average
164 current velocity profile and analysed the temporal evolution of speed and direction.

165 The Tidal Model Driver (TMD, Padman and Erofeeva, 2005) was applied to predict the
166 barotropic astronomical tidal variations for the duration of the cruise in order to explore
167 a tidal influence on the currents. The barotropic tidal current has a constant value at
168 each depth. The baroclinic tide (i.e., the one varying with depth) is not considered.
169 Twelve grid points inside the Kveithola Trough (between 16 and 18° E, with 1° step in
170 longitude and between 74.7 and 75.0° N and with 0.1° step in latitude) represent the
171 study area. The time series of the predicted tidal current at each grid point included
172 four semi-diurnal (M2, S2, N2, K2, oscillation period of about 12 hours) and four diurnal
173 (K1, O1, P1, Q1, oscillation period of about 24 hours) tidal constituents.

174 **2.1.3. Meteorological data and satellite images**

175 Meteorological data (air temperature, °C; 10 m wind speed, m s⁻¹, at 00, 06, 12, 18
176 UTC each day) from the European Centre for Medium-Range Weather Forecasts
177 (ECMWF), ERA 5 atmospheric reanalysis dataset (Resolution 0.25° x 0.25°), were
178 downloaded (DOI: 10.24381/cds.adbb2d47) and used to analyse weather conditions
179 in the first half of 2016 (from 1 January to 30 June).

180 Data from the Moderate Resolution Imaging Spectroradiometer (Aqua MODIS, L3SMI,
181 Global, 4 km resolution), freely available from NOAA ERDDAP platform were used
182 (Hu et al., 2012) to analyse surface chlorophyll (chl-a) distribution, over the Barents
183 Sea during May 2016, June 2016, and July 2016.

184 **2.2 Sedimentary dataset**

185 The sedimentary dataset consists of sediment cores collected at five sites (Figure 1
186 and Table 1) using a video-guided multi-corer (TV-MUC) equipped with eight
187 polycarbonate tubes, 60 cm length, 7,5 cm inner diameter. For the analysis related to
188 sediment grain size, organic matter, and foraminiferal assemblages, different cores
189 were collected at each site using the same device (PS99/02-2, PS99/05-2, PS99/06-
190 3, PS99/07-3, PS99/21-3). The sediment cores were split vertically down the middle

191 into two halves, visually logged, and fully sliced horizontally onboard at 0.5-cm
192 resolution (0–2 cm bsf), and at 1-cm resolution down to the core bottom for shore-
193 based analyses as reported in the following. For convenience, throughout the text, we
194 will refer to the cores with the abbreviated names of the sites: 02, 05, 06, 07 and 21.

195 **2.2.1 Sediment grain size**

196 Determination of the sediment grain size was performed using a Coulter Counter Laser
197 Beckman LS-230, measuring the 0.04-2000 μm fraction at 0.004 μm resolution. The
198 sediments were treated with peroxide water to remove the organic matter and
199 suspended into a 0.1% sodium-hexametaphosphate solution to prevent sediment
200 flocculation during the analysis. Each sample was left 3 minutes in an ultrasonic bath
201 prior to the measurement. The grain size results were classified according to Friedman
202 and Sanders (1978) grain-size scale. Reported for each core is the photograph of the
203 fresh sediment surface collected either in the laboratory (cores 02, 05, 06) or onboard
204 the ship (cores 07 and 21), the lithological log with indication of the sediment texture
205 and structures, and the down-core distribution of sand (white), silt (light gray) and clay
206 (dark gray) fractions. Note that: the recovered sediments were initially very dark
207 gray/black (e.g., cores 07 and 21) and quickly oxidized becoming yellowish and gray.

208 **2.2.2 Quantity and biochemical composition of sedimentary organic matter**

209 Chl-a and phaeopigment determinations of the top 2 cm of the sediment were carried
210 out fluorometrically according to Lorenzen and Jeffrey (1980). Pigments were
211 extracted with 90% acetone (12 h in the dark at 4 °C). After the extraction, the pigments
212 were analysed to estimate the quantity of chl-a and, after acidification with 0.1 N HCl,
213 to estimate the phaeopigments amount. The sum of the chl-a and phaeopigment
214 concentrations, was assumed to represent the total phytopigment concentrations then
215 converted to carbon equivalents by using the conversion factor of 40 μg of C μg^{-1}
216 (Pusceddu et al., 1999; Pusceddu et al., 2009). Such a conversion factor was used to
217 allow a proper comparison with previous investigations (Pusceddu et al., 1999; 2000;
218 2009).

219 Protein, carbohydrate, and lipid concentrations of the top 2 cm of the sediment were
220 determined spectrophotometrically (Pusceddu et al., 2009; 2010). Protein
221 concentration was obtained according to Hartree (1972) as modified by Danovaro
222 (2010). Concentrations are reported as mg albumin equivalents per dry weight g of
223 sediment. Carbohydrates were analysed according to Gerchakov and Hatcher (1972)
224 and expressed as mg glucose equivalents per dry weight g of sediment. Lipids were
225 extracted with methanol and chloroform (2:1 vol/vol) according to Bligh and Dyer
226 (1959) and then analysed according to Marsh and Weinstein (1966). Lipid
227 concentrations are reported as mg tripalmitin equivalents per dry weight g of sediment.
228 Protein, carbohydrate, and lipid concentrations were converted into carbon
229 equivalents by using the following conversion factors: 0.49, 0.40, and 0.75 g C g⁻¹,
230 respectively (Fabiano et al., 1995). The sum of protein, carbohydrate, and lipid carbon
231 was referred to as biopolymeric C (BPC), while bioavailable carbon (BAC)
232 concentration was calculated as the sum of digestible proteins and carbohydrates
233 converted into carbon equivalents by using the same factors as for their total pools
234 (Danovaro et al., 2001). The contribution of chl-a concentrations converted into C
235 equivalent to biopolymeric C concentrations was used as a descriptor of the ageing of
236 sediment organic matter (Pusceddu et al., 2010; Pusceddu et al., 2011). For each
237 biochemical assay, blanks were obtained using pre-combusted sediments (450 °C for
238 4 h). All the analyses were performed as three pseudo-replicates, with about 1 g of
239 sediment per sample.

240 **2.3 Sampling and treatment of the foraminiferal faunas**

241 One CTG and two RB subsamples for living foraminiferal analysis were obtained using
242 Plexiglas corers with inner diameters of 3.6 cm (surface area 10.18 cm²), inserted
243 manually into the multi-core samples after the TV-MUC recovery at each site. CTG-
244 labelled cores for each site were opened on board and sliced horizontally at every 0.5
245 cm for the uppermost 2 cm and at every 1 cm in the interval between 2–10 cm core
246 depth. Each slice was incubated in a refrigerator for 12-15 hours in Cell Tracker Green
247 CMFDA (CTG) (1 μM final concentration), following the staining procedure as indicated
248 in Pucci et al. (2009). After incubation, the samples were fixed in 10% formalin buffered
249 with sodium borate solution. RB-labelled cores were frozen on board at -20°C, as
250 performed by many of ecological studies of meiofauna (e.g., Gambi et al., 2016), and

251 sliced at the laboratory of Paleoecology of the Department of Life and Environmental
252 Science (DISVA_Italy) using the same down-core sampling resolution of the CTG-
253 samples. The sediment samples were then stained with Rose Bengal (1g L⁻¹) and fixed
254 in 4% formalin buffered with sodium borate solution for 48 h. After staining, both CTG-
255 and RB-labelled samples were sieved through 63, 150, and 500 µm mesh sieves to
256 evaluate the size structure of the living foraminiferal assemblage. The residues were
257 kept wet and hand-sorted in water using a fluorescence binocular microscope and a
258 binocular microscope for CTG-stained and Rose-Bengal-stained benthic foraminifera,
259 respectively. The processed samples were then stored in 4% buffered formalin
260 solution. Hard-shelled polythalamous foraminifera (agglutinated and calcareous
261 species) were stored in micropaleontological slides. Soft-shelled monothalamous
262 species were placed in cavity slides in glycerol and photographed under a compound
263 microscope (Nikon Eclipse E600 POL). Few fragments of branching and tubular
264 foraminifera (i.e., *Hyperammina*, *Rhizammina*) were counted but not included in the
265 data analysis because their fragile, easily breakable tests can mislead the correct
266 determination of their occurrence. The hard-shelled agglutinated group included both
267 monothalamous (i.e., *Lagenammina* genus) and polithalamous species. Taxonomy for
268 hard-shelled polythalamous foraminifera (agglutinated and calcareous taxa) followed
269 Loeblich and Tappan (1953), Seidenkrantz (1995), Majewski and Zajackowski
270 (2007), and Sabbatini et al. (2007), whereas soft-shelled monothalamous foraminiferal
271 taxonomy, followed Gooday et al. (2010), Majewski et al. (2005), and Sabbatini et al.
272 (2013).

273 All the living specimens were counted, their numbers standardised per 10 cm², and
274 the proportion of the main groups calculated. To describe the vertical distribution of
275 the total faunas or individual taxa, we used the average living depth (ALD, Jorissen et
276 al., 1995), which allows a prompt description of the microhabitat patterns. The
277 following equation allows us to calculate the ALD:

$$278 \quad \text{ALD}_x = \sum_{i=0,x} (n_i D_i) / N,$$

279 where x is the lower boundary of the deepest sample; n_i the number of individuals in
280 interval i ; D_i the midpoint of sample interval i ; N the total number of individuals for all
281 levels.

282 Faunal biodiversity was estimated using different diversity indices: species richness
283 (S) measured as the number of species, dominance measured by the Simpson (1-D)
284 index, species diversity ($H \log_e$) measured by the Shannon–Wiener (H) information
285 function, and species evenness (J) measured using the Pielou (1975) index. The
286 statistical PAST software (Paleontological Statistics; Version 3.12'; Hammer et al.,
287 2009) calculated the indices for each level and the indices for the overall 0-10 cm.

288 **2.4. Statistical analysis**

289 To test differences in community composition among sites, one-way ANOSIM was
290 applied to the results obtained from both CTG and RB-treated samples. SIMPER
291 analysis was used to assess the dissimilarity percentage between foraminiferal
292 assemblages and biochemical compounds and to identify which species contributed
293 most to the observed dissimilarities between sites. To identify the potential
294 relationships between environmental variables and foraminiferal species composition,
295 a canonical correspondence analysis (CCA) was performed on the assemblages
296 determined on CTG-labelled samples only. All statistical analyses were carried out
297 using the software Past 3'12 (Hammer et al., 2009).

298 **3. Results**

299 **3.1. Water column properties in the Kveithola Trough**

300 **3.1.1. Thermohaline properties**

301 Exploring the dataset collected in June 2016 (Figure 2a), we observe that θ ranges
302 between 3.37 and 6.93 °C, and S between 34.83 and 35.15 (Figure 2b). High θ and S
303 mark the plausible characteristic values of the Atlantic Water, while low θ and S
304 indicate influence of the Polar Water advected likely from the surrounding northern
305 shelf area (i.e., from Spitsbergen). More in detail, we consider the Atlantic Water
306 properties within the intervals of 4.00 – 7.00 °C for θ , and of 35.10 – 35.15 for S,
307 resulting in 27.5 - 27.83 kg m⁻³ for σ_θ . The Polar Water intervals are instead 3.00 -
308 4.50°C, 34.80 - 35.04, for θ and S respectively, corresponding to 27.6 - 27.85 kg m⁻³
309 for σ_θ . The wide range for Polar Water salinity suggests different pathways or origins
310 of the Polar Water that may be present in the Kveithola Trough (less denser and
311 fresher are probably remnants of the melt water in the upper layers).

312 Overall, the water column inside the Kveithola Trough seems to be a complex mixture
313 between the two main water masses, probably due to both isopycnal and diapycnal
314 mixing (Figure 2b). The spatial distribution is varying in a way that the Atlantic Water
315 layer is thicker near sites 02 and 05 (outer shelf and central deep area), while the Polar
316 Water dominates near sites 06 and 07 (inner shelf) (Figure 2c, d). In the remaining
317 central zone, near site 21, the upper 150 m layer has prevalent Atlantic Water like
318 characteristics, while the deep layer has predominantly Polar Water like
319 characteristics. The low density in the surface layer in the western and central parts of
320 the study area is mainly driven by high θ (Figure 2e). Likewise, the highest densities
321 in the bottom layer of the northern flank are driven by low θ values. The DO (Dissolved
322 Oxygen) concentrations in the water column (Figure 2f) are minimal in the surface
323 layer over the entire area, while the highest values are associated with the lower θ
324 values of the Polar Water. Where the Atlantic Water dominates, DO values decrease.
325 However, approaching the deep layer, near the seabed, the DO values never drop
326 down substantially. BT (Figure 2g) is often low (indicating a large presence of organic
327 and inorganic particles) in the upper 50 m, where also DO values are low. In general,
328 we found higher BT values (i.e., lower presence of particles) below 100 m depth. Then,
329 BT diminishes locally as approaching the seabed, like at site 06, and in the areas of
330 steep bottom slope (e.g., between sites 05 and 21) where the bottom currents and the
331 local morphology probably favour sediment resuspension. Fluorescence values
332 (Figure 2h) are high in the upper layer, especially at stations 8, 10, and 25.

333 **3.1.2. Ocean currents**

334 Measured data revealed a large spatio-temporal variability of the currents within the
335 Kveithola Trough, as we illustrate for the selected sediment sampling sites 02, 05, 06,
336 07, and 21 (Figure 3). The vertical profile of the currents speed at each site is an
337 average obtained from several vertical velocity profiles recorded during the
338 hydrological and geological data acquisition (Figure 3). The current speed varied
339 between almost 0 and 0.30 m s^{-1} . Higher speeds are recorded in the layer between 70
340 m and 150 m water depth, and the largest values are observed at site 05 (main drift).
341 The near-bottom average currents have low values ranging between 0.02 and 0.06 m
342 s^{-1} possibly due to the effect of the bottom friction. The large variability of the ocean
343 currents, in terms of both speed and direction (the latter not shown) was largely

344 influenced by tidal currents in the area. The speeds of simulated barotropic tidal
345 currents during the sampling period varied between 0.02–0.20 m s⁻¹, with direction
346 veering in a clockwise sense, with a typical semi-diurnal period (about 12 hours). The
347 tidal currents were larger along the southern and northern flanks, likely due to the
348 effects induced by the sea bottom morphology (i.e., shallower depths) and weaker in
349 the deep central area. The tidal effects on the local currents are clearly visible from
350 the profiles recorded on different days at the same sites (Figure 3a-f). In particular, at
351 site 05 the maximum speeds (> 0.20 m/s) were recorded at different depths (120 m
352 and 170 m, respectively) on the two days of measurement (19 and 20 June, Figure
353 3c, d), while at site 06 speeds in the bottom layer on 20 June were larger than those
354 recorded on the previous day (Figure 3e, f).

355 **3.2. Chlorophyll (Chl-a) surface measurements from satellite**

356 Monthly averaged concentration of Chl-a deriving from satellite images for three
357 months (May to July 2016, Figure 4) varies significantly both in time and space. High
358 Chl-a concentration over the Kveithola Trough is observed in June 2016 (Figure 4b),
359 likely due to the response of the marine environment to harsh meteorological
360 conditions (i.e., high wind speed) that enhanced water mixing and nutrients re-
361 distribution. Also, lateral advection and mesoscale activity can be responsible for
362 sediment resuspension in shallower areas, nutrient increase in the upper layer, and
363 the consequent occurrence of algal blooms that cause chl-a increase at the surface.

364 **3.3 Sediment characteristics and grain size**

365 Core 02 located in the outer Kveithola Trough (Figure 1), recovered greyish sediments
366 composed by silty-sands (0–8 cm bsf) and sandy-silts (8-14 cm bsf) containing
367 abundant Ice-Rafted Debris (IRD). The base of this coarse-grained interval is irregular
368 and overly mottled silty clay sediments. The sand content at this site is greater than
369 50% in the upper part of the core and rapidly decreases down-core.

370 Cores 05, 06, 21, and 07 located in the inner Kveithola Trough and along the *Northern*
371 *Channel* (Figure 1), recovered very dark gray/black sediments having a very strong
372 smell of H₂S. The sediments are finer-grained with respect to core 02 having, however,
373 a relatively consistent content of sand (15–30%). The sediments are strongly
374 bioturbated with a common/abundant presence of shells.

375 **3.4 Food quantity and quality at the seafloor**

376 Table 2 summarises the concentrations of all investigated biochemical compounds, as
377 well as the contribution of the algal fraction to biopolymeric C. The total phytopigment
378 content varies significantly among the sampled sites of the Kveithola Trough, with
379 values ranging from $7.56 \pm 0.55 \mu\text{g/g}$ in the outer shelf (site 02), to $61.92 \pm 4.4 \mu\text{g/g}$ in
380 the *Northern channel* (site 07). A large variability characterises the total carbohydrate
381 concentrations, with the lowest value at site 02 ($2.34 \pm 0.27 \text{ mg/g}$) and the highest at
382 site 07 ($7.02 \pm 0.79 \text{ mg/g}$).

383 Similar patterns are generally observed also for lipid and protein concentrations. The
384 bioavailable carbon (BAC) is lower at the sites 02 and 21 (value of 2.52 ± 0.82 and
385 $3.51 \pm 1.4 \text{ mg/g}$ respectively), whereas at the innermost sites the BAC is as high as
386 $6.23 \pm 0.1 \text{ mg/g}$ and $5.97 \pm 0.39 \text{ mg/g}$ at sites 06 and 07, respectively. The contribution
387 of the C associated with the algal fraction to the biopolymeric C changes significantly
388 across the sampling sites, ranging from 10% at site 02 to 34% at site 07.

389 **3.5 Foraminiferal assemblages**

390 CTG-labelled living foraminiferal abundance for the fraction $> 63 \mu\text{m}$ (0-10 cm) has
391 values increasing from 103 ind./10 cm² at site 21, to 792 ind./10 cm² at site 05 both
392 located in the central area of the trough (Figure 6a), whereas according to RB-labelled
393 samples the abundance increases from 834 ind./10 cm² at site 02 to 1571 ind./10 cm²
394 at site 06 (Figure 6c). Regarding the three different fractions, total densities of living
395 foraminifera (both CTG and RB methods) in the 0-10 cm interval showed that the
396 fraction 63-150 μm was the most abundant at sites 02, 05, and 06 and less abundant
397 at the sites 07 and 21 (CTG) where the fraction 150-500 μm is, instead, the dominant.
398 The fraction $> 500 \mu\text{m}$ represented only a minor contribution and showed comparable
399 values at all sites using the two different methods (Figure 6b, d). It is clear that the
400 total abundance evaluated by the CTG method was lower with respect to those
401 obtained by the RB staining protocol.

402 Taxa composition for the CTG cores, for the fraction $> 63 \mu\text{m}$ (total assemblage 0-10
403 cm, Figure 7a), shows that the polythalamous calcareous species represent in all sites
404 the most abundant group ($> 40\%$), except at the site 06, where the most abundant
405 group is the monothalamous (57.9%). The second abundant group is the

406 monothalamous with the percentage varying from 23.0% at the site 07 to 57.9% at the
407 site 06. Polythalamous agglutinated species are present at all sites with percentages
408 varying from 9.5% at site 06 to 27.6% at site 05.

409 In the RB case, the fauna composition in the fraction $> 63 \mu\text{m}$ (Figure 7b) is dominated
410 by polythalamous calcareous foraminifera, which represent between 57.0% (core 06)
411 and 78.0% (core 21) of the total assemblage. Polythalamous agglutinated group is
412 well represented at all sites with the percentages varying from 12.2% at site 21 to
413 33.4% at site 07, while monothalamous group is present in all sites with less
414 percentage, between 5 and 20%. For both staining methods, the miliolid group is rare
415 at all sites, representing less than 2%. The CTG method shows an overall greater
416 faunal diversity than the RB, where the polythalamous calcareous group dominates
417 the assemblages. A total of 74 species CTG-labelled (116 RB-stained) are identified
418 (0-10 cm layers, $> 63 \mu\text{m}$), of which 30 (45 RB-stained) are polythalamous calcareous
419 hyaline, 11 polythalamous agglutinated (24 RB-stained), and only 7 miliolids (8 RB-
420 stained). We found 26 monothalamous organic groups (37 RB-stained). The majority
421 of which are morphotypes; most of them belonging to well-known and widespread
422 genera of the polar environments, as *Cylindrogullmia*, *Gloiogullmia*, and *Micrometula*.
423 Plates IV -V show some examples.

424 The total living foraminiferal assemblages for the fraction $> 63 \mu\text{m}$ in CTG-labelled
425 samples, show the highest species richness at sites 05 and 07 with 39 identified
426 species, followed by sites 02 and 06 with 35 and 34 identified species, respectively.
427 The lowest value is observed at site 21 (24 species). The Simpson index is very high
428 at sites 02, 21 and 07 (0.93 and 0.89, respectively) while it decreased in the other sites
429 (< 0.85 , Table 3). The Shannon index is very high at all sites (> 2.10 , Table 3). The
430 equitability value decreases from site 02 (0.87) to site 06 (0.58). Plate I report some
431 examples of CTG-labelled foraminifera, observed using a fluorescence binocular
432 microscope.

433 In the RB-labelled samples, the highest species richness is recognized in site 02 (61
434 species), followed by sites 05 and 07 (48 and 47 species respectively), whereas in
435 sites 21 and 06 present a total of 39 and 43 species respectively. Conforming to the
436 CTG-method, the Simpson index with RB-method is very high at all sites, ranging from
437 0.95 at the site 02, to 0.92 and 0.91 at the sites 21 and 07, and 0.89 at the sites 05

438 and 06. Also, the Shannon's index maintains a similar trend along the transect,
439 decreasing from the site 02 (3.41) to the site 07 (2.96), and the Equitability J shows a
440 similar trend of Shannon's index, with value varying from 0.82 (site 02) to 0.76 (site
441 07_Table 3).

442 The vertical distribution of living foraminifera at the site 02, for both labelled methods,
443 shows a general low density compared to the other sites, with a clear discrepancy of
444 the vertical distribution between the two applied methods. The foraminiferal
445 assemblages are distributed down to 7 cm in CTG-labelled samples, and 10 cm for
446 the RB-labelled ones (see figure 8-9). The most abundant species are *Pullenia*
447 *bulloides* and *Melonis barleeanus* (Plate I-II) in the fraction 150-500 μm and
448 *Psammophaga arctica* in the fraction 63-150 μm . Whereas the RB samples highlight
449 also the presence of the mono/polythalamous agglutinated species *Lagenammina*
450 *diffflugiformis* and *Hormosinella guttifer* in the fraction 150-500 μm , and the species
451 *Alabaminella weddellensis* in the fraction 63-150 μm .

452 At the inner sites 21, 05, 06, and 07, the discrepancy in the vertical distribution of the
453 foraminiferal assemblages is also maintained (down to 7 cm for the CTG method, and
454 10 cm for the RB method). The most abundant species, for both methods, in the
455 fraction 150-500 μm are *Nonionellina labradorica* and *Globobulimina auricularis* (Plate
456 I-II). In addition, at site 05 there is a consistent presence of polythalamous calcareous
457 species *Islandiella helenae* and *Pullenia bulloides*. However, the monothalamous
458 organic-wall species *Micrometula* sp. and *Cilindrogullmia* like, the polythalamous
459 calcareous *Nonionella auricula* and the agglutinated genus *Reophax* dominate the 63-
460 150 μm fraction. In addition, the RB-stained protocol highlights the presence of the
461 polythalamous calcareous *Bolivinellina pseudopunctata* (all inner sites) (Plate II),
462 *Alabaminella weddellensis* and *Buccella frigida* at site 21, and the polythalamous
463 agglutinated *Adecortryma glomeratum* at sites 21 and 07.

464 A few species, *N. labradorica*, *G. auriculata*, and *R. scorpiurus* (Plate I-II-III), are
465 representative of the fraction > 500 μm recovered at all sites and using both methods,
466 although there is a clear discrepancy in their vertical distribution (uppermost 5 cm)
467 using the two labelled methods (CTG and RB). Also, the average living depth (ALD₁₀)
468 clearly indicates that the living depth of benthic foraminifera is shallower with CTG

469 method (value ranging between 0.5-3 cm) compared to the RB method (values varied
470 from 1.5 to 4 cm) (Table 3 and Figure 8-9).

471 **3.6 Statistical analysis**

472 The ANOSIM test applied to the abundance of CTG-labelled foraminifera shows
473 significant pairwise comparisons between the outer (site 02), the inner (sites 21, 05
474 and 06), and *Northern channel* (site 07) ($R = 0.14$ and $p < 0.0007$). Likewise, for RB
475 labelled foraminifera, the test reveals significant differences in the foraminiferal
476 assemblage among the three areas (global $R = 0.176$, $p < 0.0001$).

477 As we will explain in the discussions, the CTG-stain appears to be the best method to
478 obtain information about living foraminiferal distribution in the Kveithola Trough then,
479 in the following, most of the discussion will consider the CTG-labelled assemblages
480 only. The site's taxon abundances were plotted against environmental variables
481 including water depth, sediment grain size, and percentages of bioavailable Carbon
482 (BAC), biopolymeric Carbon (BPC), and benthic pigments (Figure 10). A clear
483 separation between the sites is visible. Site 02 is characterized by sandy sediments
484 with prevailing monothalamous organic-wall species *P. arctica* and polythalamous
485 calcareous foraminifera as *C. reniforme*, *P. bulloides* and *M. barleaanus*. At site 05,
486 there is a clear correlation between the most abundant species (e.g., *B.*
487 *pseudopunctata*, *R. fusiformis*, *I. helenae* and *L. difflugiformis*) and the quality of
488 organic matter (BPC and BAC). Site 06 is characterized by high concentration of Feo
489 with dominance of the monothalamous organic foraminifera *Cylindrogullmia*-like.
490 Finally, another important correspondence links the presence of fine-grained
491 sediments characterising sites 07 and 21, with the high organic matter concentration,
492 especially of benthic pigments, and the dominance of foraminifera species such as *G.*
493 *auriculata* and *N. labradorica*.

494 **4. Discussion**

495 **4.1 Foraminiferal assemblages of the Kveithola Trough**

496 **4.1.1 Comparison of staining methodologies**

497 Before we start to discuss our results, we want to draw the attention to the differences
498 we observed by applying the RB and CTG methodologies. In most ecological studies,
499 foraminifera are recognised as living by staining with RB that, unfortunately, is not a
500 very efficient method for its capacity to react with protein which persists in the
501 cytoplasm for a long time after death (Bernhard et al., 2006), especially in anoxic
502 sediments, where the protoplasm or the organic matter decay may be relatively slow.
503 On the contrary, the CTG method (Bernhard et al., 2000) allows us to distinguish with
504 much more detail between living and dead individuals. In fact, CTG produces
505 fluorescent products after modification by intracellular esterases that, after the cellular
506 death, are decomposed in a few hours or days depending on the environmental
507 conditions (Bernhard et al., 2006). However, the CTG only works in relatively shallow
508 settings where foraminifera remain alive and active when recovered, in fact, at greater
509 depths (>2000-3000 m) most forams will not survive when brought to the sea surface,
510 and so CTG will not work. Moreover, it is also more expensive than RB and requires
511 the use of a fluorescence binocular microscope for sorting, whereas RB is cheaper
512 and easier to use.

513 The comparison between CTG and RB methods in this study reveals that the RB
514 staining evidences a higher number of living foraminifera in all cores and all depth
515 levels with respect to CTG method (Figure 8-9). Previous studies, as in the
516 experimental approach by Pucci et al. (2009) or the deep-water sediment cores
517 analyzed by Bernhard et al. (2006), already demonstrated the discrepancy in density
518 determinations between the two methods. Bernhard et al. (2006), however, clarified
519 that the conditions and species used in their study may not be representative of all
520 foraminiferal species and environmental conditions. In this regard, Figueira et al.
521 (2012), in their study for the identification of live agglutinated foraminifera from New
522 Zealand salt-marsh, reported that the RB performed as well as CTG and no strong
523 density differences were observed. They reported as a possible explanation the fact
524 that the cytoplasm of dead foraminifera takes longer to degrade in lower temperature

525 of deep-sea environments compared to warmer salt-marsh habitats, where aridity
526 could reduce the water level promoting oxidation and degradation of cytoplasm.

527 In our samples, although considerable differences in the vertical distribution and
528 presence absence of benthic species are observed using different labelling methods,
529 the RB method detects a deeper distribution of the living species, probably due to
530 inferences with the increase of organic matter accumulation and the consequent
531 reduction of oxygen content. Consequently, also, the average living depth obtained is
532 deeper (Table 3). The CTG method shows mainly an epifaunal and superficial infaunal
533 foraminiferal microhabitat, whereas in the RB method prevailed a superficial and deep
534 infaunal behaviour at all sites. This difference is more evident at site 21 (central part
535 of Kveithola Trough). In addition, almost all abundant species of the CTG labelled
536 cores are well represented also in the RB-stained cores, but some of the most
537 abundant RB species are less represented or even absent in the CTG labelled cores
538 (Figure 8, 9). This fact is particularly evident in the smaller size fraction 63-150 μm .
539 For example, the polythalamous calcareous species *Alabaminella weddellensis*, the
540 polythalamous agglutinated species *Adercotryma glomeratum* and *Textularia aerlandi*
541 (Plate III), and the polythalamous calcareous species like *Astrononion hamadaense*,
542 *Buccella frigida*, *Melonis barleeanus*, and *Trifarina* spp. Some of these species are
543 reported among the most abundant dead foraminiferal assemblages of the Kveithola
544 Trough spanning the last ca. 50-150 years of the same sites (Sojo-Gamboa et al.,
545 submitted). This fact suggests, as stated by Bernhard et al. (2006), that RB stains
546 dead specimens for months to even years, creating false positives that might affect
547 the ecological interpretation. Moreover, the oceanographic conditions of the arctic
548 Kveithola Trough, the high sedimentation rate, and the rapid burial, lead to an increase
549 of the organic matter accumulation and preservation. As a consequence, the organic
550 matter decay is slow in the foraminiferal shells, causing the foraminiferal abundance
551 overestimation.

552 Therefore, the data presented above suggest that the RB method has to be used with
553 caution, while CTG results appear more reliable. In the next paragraphs, we will
554 discuss more in detail the CTG assemblages (in terms of density, taxonomic
555 composition and vertical distribution) and their relationships to the environmental
556 conditions (oceanography and trophic status) of this area.

557 **4.1.2 Significance of density, taxonomic composition, and vertical distribution**
558 **of foraminifera (CTG-labelled) at the Kveithola Trough**

559 Changes in the benthic foraminiferal fauna distribution strongly depend on organic
560 matter and oxygen availability, redox chemistry, bottom currents, and/or the interaction
561 between these parameters (Murray, 2006). Further, in sediment inhabited by
562 macrobenthic communities, the vertical zonation of living foraminifera can be affected
563 by bioturbation (Bouchet et al., 2009). Our data evidence that the faunal distribution
564 varies significantly along the main longitudinal transect of the Kveithola Trough despite
565 its short length. The statistical ANOSIM and CCA analyses indicate significant
566 differences in the composition of foraminiferal communities between three zones
567 (Figure 10): the outer Kveithola Trough (site 02); the central area of the Trough (main
568 and minor drifts) and the *Northern Channel* (sites 05, 06 and 07 respectively); and site
569 21 located close to the Main drift. Furthermore, foraminiferal density, species richness,
570 and composition show remarkable differences among these zones, concerning their
571 size with small foraminiferal assemblage (63-150 μm) dominating at all studied sites.

572 **4.1.2 The outer Kveithola Trough (site 02)**

573 The warm and saline AW transported northward by the WSC, dominates the outer part
574 of the Kveithola Trough (400–450 m bsl), which is also the deepest studied area. The
575 WSC sweeps the outer seafloor removing the fine sediment fraction, as indicated by
576 the lithology of core 02 (see also Caricchi et al., 2018), contributing to maintain a well-
577 oxygenated environment that is reflected by the high biodiversity of the foraminiferal
578 assemblage (Table 3). Such persistent hydrodynamic processes do not favour the
579 accumulation of the organic matter reducing the faunal abundance (171 ind./10cm²,
580 Figure 6a). In fact, during the oceanographic survey, ocean currents at 40-50 m above
581 the seabed had speeds between 0.08 and 0.10 m/s depending on the tidal conditions,
582 and they could be reasonably higher during specific events (i.e., strong atmospheric
583 perturbations, density driven currents during winter sea-ice formation). The BPC, BAC,
584 and the algal carbon contribution to BPC values (Table 2) indicate lower bioavailability
585 of sediment organic carbon, leading to a poor sediment oxygen consumption by
586 benthic communities (e.g., Pusceddu et al., 2009). These low values might be related
587 to persistent hydrodynamic processes that inject more refractory organic matter pools,
588 like carbohydrates, in the bottom layer (e.g., Pusceddu et al., 2016) but may also be

589 related with a reduced primary production phase as suggested from the analyses of
590 Chl-a average distribution from satellite images (Figure 4). Previous studies conducted
591 by Włodarska-Kowalczyk and Pearson (2004), demonstrated that also in the food-
592 limited Arctic Ocean sediments, the levels of primary production and food supply can
593 shape foraminiferal assemblages both in terms of species composition and standing
594 stocks.

595 At station 02, the abundance of foraminifera decreases linearly with the depth in
596 sediment, and the fauna is characterised by high biodiversity epifaunal specimens
597 ($ALD_{10}=1.06$ cm, Table 3) adapted to poor food quality. Therefore, the foraminiferal
598 epifaunal-shallow infaunal microhabitat is interpreted as a better response of
599 individuals to exploit the available food and oxygen from the bottom water (e.g.,
600 Schonfeld et al., 2002; Jorissen et al., 1995). The faunal density is low (171 ind./10cm²,
601 Figure 6a), and the most abundant species is the monothalamous organic
602 *Psammophaga arctica* (Figure 8), particularly in the intermediate and deep layers of
603 the fraction 63-150 µm. Several authors consistently reported the presence and
604 dominance of *Psammophaga* morphotypes, behaving as an opportunist taxon. Among
605 them, Sergeeva et al. (2010) reported its presence from hypoxic and sulphidic settings
606 near active methane seeps in the Black Sea, whereas Larkin and Gooday (2004)
607 described *Psammophaga* sp. from an intertidal site on the southern coast of England.
608 We suggest that in the Kveithola area, this species displayed an opportunistic
609 behaviour in response to low quality of organic carbon pulse, differently to what was
610 stated by Sabbatini et al. (2012). The other abundant species *Cassidulina reniforme*
611 is, instead, often associated with low temperature and seasonal ice cover in different
612 areas of the Barents Sea (Hald and Korsun, 1997; Polyak et al., 2002; Saher et al.,
613 2009; 2012). Interestingly, other monothalamous species such as *Micrometula* sp.
614 and *Cylindrogullmia*-like (Plate I) are represented only in the fraction 63-150 µm. Other
615 species, i.e., *P. bulloides* and *T. angulosa* are representative species of the fraction
616 150-500 µm at site 02 (Figure 8) and are opportunistic species that respond to pulsed
617 phytodetritus supplies (Korsun et al., 1995; Włodarska-Kowalczyk, 2012; Rasmussen
618 and Thomsen, 2017).

619 **4.1.3 Main, Minor drift, and Northern Channel (sites 05, 06, and 07)**

620 This inner area undergoes continuous fine-grained sediment deposition under the
621 transport by bottom currents linked to the inflow of the WSC having a general anti-
622 clockwise circulation in the trough (enters the trough in the south-western area and
623 flows out in the north-western). The bottom current is periodically refilled by fine
624 grained sediments transported into the system by dense waters coming from the north-
625 east (Lantzsch et al., 2017). In the inner area our data evidenced high nutritional
626 quality organic matter input to the seafloor (i.e., BAC and Chl-a Table 2) related to cold
627 and less saline Arctic Water input. Indeed, organic matter analyses showed that, in
628 both the Drift area and the *Northern Channel*, the organic carbon load considered as
629 BPC is comparable to values typically encountered in eutrophic systems varying from
630 4.5 mg/g to 6.9 mg/g (e.g., Dell'Anno et al., 2002), and that the BAC concentration is
631 higher than in the outer part (Table 2). The algal blooms in this area are determined
632 by the increasing nutrient availability due to seasonal melting of the ice and are more
633 intense in the vicinity of the ice, therefore towards the continent (in our case towards
634 the inner area). However, during the year 2016, no seasonal sea-ice was observed in
635 the Kveithola area. Instead, on-board meteorological observations and the analysis of
636 the ECMWF-ERA5 meteorological data (air temperature, wind speed, and direction)
637 averaged for the study area (Figure 11), evidence that the survey took place in a period
638 characterized by calm weather conditions. In addition, from the time series in figure
639 11, it is evident that the air temperature remained permanently above 0 °C since mid-
640 May 2016, and that the only significant northerly wind event (> 10 m/s) that caused a
641 drop in air temperature and water mixing, occurred in early June, i.e., a few weeks
642 before our passage. This fact, which triggers nutrient upwelling of the water column
643 promoting algal blooms in summer, may help to explain the higher Chl-a concentration
644 over the Barents Sea observed from satellite data in June 2016 (Figure 4).

645 Such oceanographic and biogeochemical conditions explained above, may justify the
646 decreased diversity (Table 3) and a community structure dominated by fewer,
647 specialised taxa with high density (Figure 8), observed in these sites. For example,
648 species such as *Nonionellina labradorica*, *Nonionella auricula*, *G. auriculata*, and
649 *Reophax fusiformis* (Figure 8) (Plate I-II-III) dominate the foraminiferal assemblage
650 and highlight the presence of an organic-rich sediment and oxygen-depleted
651 environments. Despite this, there are many studies in other areas of the Barents Sea
652 that reported the decreasing of these species for cold water species (Saher et al.,

2009; 2012). The calcareous species *N. labradorica*, typical of the size fraction 150-500 μm , is replaced by the species *N. auricula* in the finest fraction (63-150 μm). A high percentage of agglutinated species including monothalamous and polythalamous taxa, is also recorded (Figure 7). Their abundance, in the Arctic Ocean, is on a regional scale related to carbon flux (Wollenburg et al., 2007). The most abundant species are *R. fusiformis*, *R. scorpiurus*, and *Lagenammia difflugiformis* (Plate III), which are opportunistic species exploiting enhanced food conditions, and also tolerant to hypoxic environments (Ernst and van der Zwaan, 2004; Caille et al., 2015). Furthermore, *L. scottii* is also considered an indicator of benthic eutrophication in shallow waters (e.g., Sabbatini et al., 2012) and together with *R. scorpiurus*, they are representative of high sedimentation rate in the arctic region (e.g., Murray, 2006; Jernas et al., 2018; Fossile et al., 2020) and in canyons (e.g., Di Bella et al., 2017 and references therein). In addition, these two species are only represented in the fraction 63-150 μm .

Interestingly, in the fraction 63-150 μm , delicate foraminiferal monothalamous taxa (organic-walled allogromiids, agglutinated saccamminids, psammosphaerids and tubular forms) are reported from all sites with a high percentage (Figure 7); the dominance of *Micrometula* and *Cylindrogullmia* morphotypes is observed, inhabiting typically the detritical layer of Arctic fjords. They have an elongated, and thread-like form that tends to be more common in deeper sediment layers. *Micrometula* seems dependent on fresh phytodetritus (Alve, 2010) while *Cylindrogullmia* lives in an extremely oxygen-deficient environment (Gooday, 2002).

4.1.4 Main drift (site 21)

A peculiar case is site 21, located at the north-western boundary of the Kveithola Main drift at the foot of a transverse GZW (Figure 12). Contrary to expectations, both foraminiferal abundance and diversity at this site are low (112 ind./10 cm^2 and 26 species, respectively) compared to the other inner sites (Figure 8 and Table 3). The foraminifera are concentrated only in the first centimetres of sediment ($\text{ALD}_{10} = 1.09$ cm), characterized by oxidized, reddish sediments (Figure 5). Below 1-cm, the colour turns black due to sulphate reduction in organic-matter-rich sediments (strong smell of H_2S). In such conditions, the absence of foraminifera suggests a eutrophic and anoxic environment not suitable for their colonisation.

684 Based on the oceanographic characteristics, different water masses affect the vertical
685 stratification in the inner Kveithola, particularly in its northernmost part. The deep layer
686 is influenced by cold and dense Arctic waters originating from sea-ice formation. Such
687 waters are transported southwards by the ESC. The intermediate layer is instead
688 mainly occupied by AW, while the surface is influenced by fresher water due to the
689 sea-ice melting. This persistent stratification, interrupted only by strong meteorological
690 events and local amplification of the oceanic currents due to e.g., tidal influence and
691 bathymetric constraints, could reduce the vertical gas exchanges at the sediment-
692 water interface leading to fast oxygen consumption by bacteria and consequent
693 sediment anoxic conditions and lower availability of organic matter to benthic
694 communities (Heinz et al., 2005; Pusceddu et al., 2009). On the contrary, local mixing
695 events can lead to the oxygenation of the deep layer which manifests in the deposition
696 of light-coloured sediment. We therefore infer that at the time of our passage, the
697 oceanographic conditions reflected oxygenated conditions and it may explain the
698 sedimentological observation reported above.

699 As for the foraminiferal assemblage we infer that the benthic foraminiferal community
700 decrease in terms of abundance (112 ind./10 cm²), biodiversity (26 species), and
701 distribution correlates to the stressful environmental conditions characterizing the
702 subsurface sediment. The fraction 500-150 µm, dominated by infaunal species like *N.*
703 *labradorica* at a shallower depth, is therefore a reaction to these conditions leading
704 foraminifera to migrate upward in the sediment. In fact, previous studies (Alve et al.,
705 1990; Cedhagen, 1991; Mityaev et al., 2005) reported the presence of *N. labradorica*
706 in the Arctic areas associated with high primary productivity, significant influx of
707 organic matter to sediments, and occasional oxygen deficiency. Bernhard (1999) and
708 more recently Jauffrais et al. (2018) defined *N. labradorica* as a kleptoplastic species.
709 In fact, these species sequester plastids that provide an unknown metabolic
710 advantage that permits the foraminifera to reside in these habitats. Furthermore, the
711 dominance of polythalamous calcareous species *G. auriculata* (Plate I-II), justify the
712 stressful area conditions. In fact, *Globobulimina* spp. have been found deep in the
713 sediments within or below the oxic-anoxic interface and referred to deep infauna in
714 many meso-eutrophic settings (Fontanier et al., 2002; Licari et al., 2003; Koho et al.,
715 2008). Therefore, we could hypothesise that the first centimetres of site 21, which differ

716 from the lower part of the core, correspond to a rapid turnover of opportunistic
717 foraminiferal species able to consume the refractory component of the organic matter.

718 5. Conclusions

719 This work analyses the living benthic foraminifera of the Kveithola Trough. Our data
720 evidence that the faunal distribution varies significantly along the main longitudinal
721 transect of the Kveithola Trough despite its short length.

722 Moreover, the analysis of the benthic foraminiferal assemblage compared to the
723 sedimentary and oceanographic features, and the organic matter content in the
724 Kveithola Trough (NW Barents Sea) evidence that one of the main determining factors
725 in the spatial distribution, density, and species composition of the benthic foraminiferal
726 community is the supply of organic matter and its quality. In the outer site O2, the low
727 bioavailability of sediment organic carbon and high hydrodynamism, which can
728 enhance sediment resuspension injecting in the bottom water organic matter pools
729 more refractory in nature (e.g., carbohydrates), are reflected by the low density (171
730 ind./10 cm²) but high biodiversity (37 species) characterising the microfauna. The
731 fauna is dominated by the monothalamous organic species *Psammophaga arctica*,
732 and the polythalamous calcareous species *Cassidulina reniforme*, *Pullenia bulloides*,
733 and *Trifarina angulosa*.

734 Instead, the inner trough represents a eutrophic area, where the morphological and
735 oceanographical patterns still influence the composition and accumulation of organic
736 matter. In fact, the inner part is characterized by high metabolizable compounds and
737 opportunistic species. The latter are associated with organic-rich sediment and
738 oxygen-depleted environments and are dominated by *Nonionellina labradorica*,
739 *Nonionella auricula*, *Reophax scoriurus* and *fusiformis*.

740 Particularly, at site 21 where foraminifera present low abundance and low diversity
741 (112 ind./10 cm² and 26 species, respectively), they are concentrated only in the first
742 sediment centimetre (ALD₁₀= 1.09). Here, the rapid changes of the oceanographic
743 properties and the geo-morphological characteristics, lead to a rapid burial and
744 accumulation of organic matter. Therefore, there is a light sediment colour in the first
745 centimetres. The portion below instead, shows a darker colour typical of organic matter
746 enriched sediment and is devoid of living foraminifera, suggesting a eutrophic and
747 anoxic environment that foraminifera cannot colonise.

748 Moreover, the results of this study allow us to describe the Kveithola Trough as a
749 eutrophic hot-spot due to high primary and secondary production and high nutrient
750 rates that reach the benthic community. These, added to peculiar environmental
751 conditions, shape the living benthic foraminiferal structure.

752 Finally, the comparison between RB and CTG labelling, strengthen the CTG method,
753 as the more appropriate technique to document the vitality of foraminiferal
754 assemblages also in the Kveithola Trough, where low temperatures and food-
755 rich/oxygen depleted sediments can preserve foraminiferal cytoplasm long after death.
756 The observed discrepancy between the RB and CTG density, confirms that RB
757 method commonly overestimates living foraminifera.

758

759

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770 **References**

- 771 Aagaard, K., and Greisman, P. (1975). Toward new mass and heat budgets for the Arctic
772 Ocean. *Journal of Geophysical Research*, 80(27), 3821-
773 3827. <https://doi.org/10.1029/JC080i027p03821>
- 774 Aagaard, K. (1981). On the deep circulation in the Arctic Ocean. *Deep Sea Research Part A.*
775 *Oceanographic Research Papers*, 28(3), 251-268. [https://doi.org/10.1016/0198-](https://doi.org/10.1016/0198-0149(81)90066-2)
776 [0149\(81\)90066-2](https://doi.org/10.1016/0198-0149(81)90066-2)
- 777 Aagaard, K., Swift, J. H., and Carmack, E. C. (1985). Thermohaline circulation in the Arctic
778 Mediterranean seas. *Journal of Geophysical Research: Oceans*, 90(C3), 4833-4846.
779 <https://doi.org/10.1029/JC090iC03p04833>
- 780 Aagaard, K. (1989). *A synthesis of the Arctic Ocean circulation*. Le Conseil.
- 781 Alve, E. (1990). Variations in estuarine foraminiferal biofacies with diminishing oxygen
782 conditions in Drammensfjord, SE Norway. In *Paleoecology, biostratigraphy,*
783 *paleoceanography and taxonomy of agglutinated foraminifera* (pp. 661-694). Springer,
784 Dordrecht. https://doi.org/10.1007/978-94-011-3350-0_23
- 785 Alve, E. (2010). Benthic foraminiferal responses to absence of fresh phytodetritus: A two-
786 year experiment. *Marine Micropaleontology*, 76(3-4), 67-75.
787 <https://doi.org/10.1016/j.marmicro.2010.05.003>
- 788 Bernhard, J. M., Newkirk, S. G., and Bowser, S. S. (1995). Towards a non-terminal viability
789 assay for foraminiferan protists. *Journal of Eukaryotic Microbiology*, 42(4), 357-367.
790 <https://doi.org/10.1111/j.1550-7408.1995.tb01594.x>
- 791 Bernhard, J. M. and Sen Gupta, B. K. (1999). Foraminifera of oxygen depleted environments,
792 in: *Modern Foraminifera*, edited by: Sen Gupta, B. K., Kluwer Academic Press, Dordrecht,
793 201–216. https://doi.org/10.1007/0-306-48104-9_12
- 794 Bernhard, J. M. (2000). Distinguishing live from dead foraminifera: methods review and proper
795 applications. *Micropaleontology*, 46, 38-46.
- 796 Bernhard, J. M., Ostermann, D. R., Williams, D. S., and Blanks, J. K. (2006). Comparison of
797 two methods to identify live benthic foraminifera: A test between Rose Bengal and
798 CellTracker Green with implications for stable isotope paleo
799 reconstructions. *Paleoceanography*, 21(4). <https://doi.org/10.1029/2006PA001290>
- 800 Bligh, E. G., and Dyer, W. J. (1959). A rapid method of total lipid extraction and purification.
801 *Biochemistry and Cell Biology*. <https://doi.org/10.1139/o59-099>
- 802 Bjarnadóttir, L. R., Rütger, D. C., Winsborrow, M. C. M., and Andreassen, K. (2013).
803 Grounding-line dynamics during the last deglaciation of Kveithola, W Barents Sea, as
804 revealed by seabed geomorphology and shallow seismic stratigraphy. *Boreas*.
805 <https://doi.org/10.1111/j.1502-3885.2012.00273>
- 806 Borrelli, C., Sabbatini, A., Luna, G. M., Nardelli, M. P., Saffi, T., Morigi, C., R. Danovaro and
807 Negri, A. (2011). Determination of the metabolically active fraction of benthic foraminifera
808 by means of Fluorescent In Situ Hybridization (FISH). *Biogeosciences*, 8(8), 2075-2088.
809 <https://doi.org/10.5194/bg-8-2075-2011>, 2011
- 810 Bouchet, V. M., Sauriau, P. G., Debenay, J. P., Mermillod-Blondin, F., Schmidt, S., Amiard, J.
811 C., and Dupas, B. (2009). Influence of the mode of macrofauna-mediated bioturbation on
812 the vertical distribution of living benthic foraminifera: First insight from axial
813 tomodesitometry. *Journal of Experimental Marine Biology and Ecology*, 371(1), 20-33.
814 <https://doi.org/10.1016/j.jembe.2008.12.012>
- 815 Carpenter, J. H. (1965). The accuracy of the winkler method for dissolved oxygen analysis
816 1. *Limnology and Oceanography*, 10(1), 135-140.
817 <https://doi.org/10.4319/lo.1965.10.1.0135>
- 818 Caricchi, C., Lucchi, R. G., Sagnotti, L., Macrì, P., Morigi, C., Melis, R., Caffau, M., Rebesco,
819 M., and Hanebuth, T. J. J. (2018). Paleomagnetism and rock magnetism from

820 sediments along a continental shelf-to-slope transect in the NW Barents Sea:
821 Implications for geomagnetic and depositional changes during the past 15 thousand
822 years. *Global and Planetary Change*. <https://doi.org/10.1016/j.gloplacha.2017.11.007>

823 Caridi, F., Sabbatini, A., Morigi, C., Dell'Anno, A., Negri, A., and Lucchi, R. G. (2019).
824 Patterns and environmental drivers of diversity and community composition of
825 macrofauna in the Kveithola Trough (NW Barents Sea). *Journal of Sea Research*, 153,
826 101780.

827 Cauille, C., Mojtahid, M., Gooday, A. J., Jorissen, F. J., and Kitazato, H. (2015). Living (Rose-
828 Bengal-stained) benthic foraminiferal faunas along a strong bottom-water oxygen
829 gradient on the Indian margin (Arabian Sea). *Biogeosciences*, 12(16), 5005-5019.
830 <https://doi.org/10.5194/bg-12-5005-2015>

831 Cedhagen, T. (1991). Retention of chloroplasts and bathymetric distribution in the sublittoral
832 foraminiferan *Nonionellina labradorica*. *Ophelia*, 33(1), 17-30.
833 <https://doi.org/10.1080/00785326.1991.10429739>

834 Cusson, M., and Bourget, E. (2005). Global patterns of macroinvertebrate production in marine
835 benthic habitats. *Marine Ecology Progress Series*, 297, 1-14.
836 <https://doi.org/10.3354/meps297001>

837 Danovaro, R., Dell'Anno, A., and Fabiano, M. (2001). Bioavailability of organic matter in the
838 sediments of the Porcupine Abyssal Plain, northeastern Atlantic. *Marine Ecology*
839 *Progress Series*, 220, 25-32. doi:10.3354/meps220025

840 Danovaro, R. (2010). *Methods for the Study of Deep-Sea Sediments, Their Functioning and*
841 *Biodiversity*. BocaRaton, FL: CRC Press. <https://doi.org/10.1201/9781439811382>

842 Dell'Anno, A., Mei, M. L., Pusceddu, A., and Danovaro, R. (2002). Assessing the trophic
843 state and eutrophication of coastal marine systems: A new approach based on the
844 biochemical composition of sediment organic matter. *Marine Pollution Bulletin*.
845 [https://doi.org/10.1016/S0025-326X\(01\)00302-2](https://doi.org/10.1016/S0025-326X(01)00302-2)

846 De Nooijer, L. J., Duijnste, A. P., and Van der Zwaan, G. J. (2006). Novel application of
847 MTT reduction: a viability assay for temperate shallow-water benthic foraminifera, J.
848 *Foramin. Res.*, 36, 195– 200. <https://doi.org/10.2113/gsjfr.36.3.195>

849 Di Bella, L., Pierdomenico, M., Porretta, R., Chiocci, F. L., and Martorelli, E. (2017). Living
850 and dead foraminiferal assemblages from an active submarine canyon and surrounding
851 sectors: the Gioia Canyon system (Tyrrhenian Sea, Southern Italy). *Deep Sea*
852 *Research Part I: Oceanographic Research Papers*, 123, 129-146.
853 <https://doi.org/10.1016/j.dsr.2017.04.005>

854 Du Châtelet, É. A., and Debenay, J. P. (2010). The anthropogenic impact on the western
855 French coasts as revealed by foraminifera: a review. *Revue de*
856 *micropaléontologie*, 53(3), 129-137. <https://doi.org/10.1016/j.revmic.2009.11.002>

857 Ernst, S., and van der Zwaan, B. (2004). Effects of experimentally induced raised levels of
858 organic flux and oxygen depletion on a continental slope benthic foraminiferal
859 community. *Deep Sea Research Part I: Oceanographic Research Papers*, 51(11), 1709-
860 1739. <https://doi.org/10.1016/j.dsr.2004.06.003>

861 Fabiano, M., Danovaro, R., and Frascchetti, S. (1995). A three-year time series of elemental
862 and biochemical composition of organic matter in subtidal sandy sediments of the
863 Ligurian Sea (northwestern Mediterranean). *Continental Shelf Research*.
864 [https://doi.org/10.1016/0278-4343\(94\)00088-5](https://doi.org/10.1016/0278-4343(94)00088-5)

865 Figueira, B. O., Grenfell, H. R., Hayward, B. W., and Alfaro, A. C. (2012). Comparison of Rose
866 Bengal and CellTracker Green staining for identification of live salt-marsh
867 foraminifera. *The Journal of Foraminiferal Research*, 42(3), 206-215.
868 <https://doi.org/10.2113/gsjfr.42.3.206>

869 Fontanier, C., Jorissen, F. J., Licari, L., Alexandre, A., Anschutz, P., and Carbonel, P. (2002).

870 Live benthic foraminiferal faunas from the Bay of Biscay: faunal density, composition, and
871 microhabitats. *Deep Sea Research Part I: Oceanographic Research Papers*, 49(4), 751-
872 785. [https://doi.org/10.1016/S0967-0637\(01\)00078-4](https://doi.org/10.1016/S0967-0637(01)00078-4)

873 Fontanier, C., A. MacKensen, F. J. Jorissen, P. Anschutz, L. Licari, and C. Griveaud. (2006).
874 “Stable Oxygen and Carbon Isotopes of Live Benthic Foraminifera from the Bay of Biscay:
875 Microhabitat Impact and Seasonal Variability.” *Marine Micropaleontology* 58 (3): 159–83.
876 <https://doi.org/10.1016/j.marmicro.2005.09.004>.

877 Fohrmann H., Backhaus J.O., Blaume F., Rumohr J. (1998) Sediments in bottom-arrested
878 gravity plumes: numerical case studies. *J Phys Oceanogr* 28:2250–2274
879 [https://doi.org/10.1175/1520-0485\(1998\)028<2250:SIBAGP>2.0.CO;2](https://doi.org/10.1175/1520-0485(1998)028<2250:SIBAGP>2.0.CO;2)

880 Fossile, E., Nardelli, M. P., Jouini, A., Lansard, B., Pusceddu, A., Moccia, D., Michel, E., Péron,
881 O., Howa, H. and Mojtafid, M. (2020). Benthic foraminifera as tracers of brine production
882 in the Storfjorden “sea ice factory”. *Biogeosciences*, 17(7), 1933-1953.
883 <https://doi.org/10.1594/PANGAEA.907687>

884 Friedman, G.M., Sanders, J.E., 1978. Principles of Sedimentology. John Wiley and Sons, New
885 York (792 pp.).

886 Frontalini, F., and Coccioni, R. (2011). Benthic foraminifera as bioindicators of pollution: a
887 review of Italian research over the last three decades. *Revue de*
888 *micropaléontologie*, 54(2), 115-127. <https://doi.org/10.1016/j.revmic.2011.03.001>

889 Gambi, C., and Danovaro, R. (2016). Biodiversity and life strategies of deep-sea meiofauna
890 and nematode assemblages in the Whittard Canyon (Celtic margin, NE Atlantic Ocean).
891 *Deep Sea Research Part I: Oceanographic Research Papers*, 108, 13-22.
892 <https://doi.org/10.1016/j.dsr.2015.12.001>

893 Gerchakov, S. M., and Hatcher, P. G. (1972). Improved technique for analysis of
894 carbohydrates in sediments. *Limnology and Oceanography*.
895 <https://doi.org/10.4319/lo.1972.17.6.0938>

896 Gooday, A. J., Levin, L. A., Linke, P., and Heeger, T. (1992). The role of benthic foraminifera
897 in deep-sea food webs and carbon cycling. In *Deep-sea food chains and the global*
898 *carbon cycle* (pp. 63-91). Springer, Dordrecht. [https://doi.org/10.1007/978-94-011-](https://doi.org/10.1007/978-94-011-2452-2_5)
899 [2452-2_5](https://doi.org/10.1007/978-94-011-2452-2_5)

900 Gooday, A. J., Kamenskaya, O. E., and Soltwedel, T. (2010). The organic-walled genera
901 *Resigella* and *Conicotheca* (Protista, Foraminifera) at two Arctic deep-sea sites (North
902 Pole and Barents Sea), including the description of a new species of *Resigella*. *Marine*
903 *Biodiversity*, 40(1), 33-44. <https://doi.org/10.1007/s12526-009-0031-6>

904 Grebmeier, J. M., Overland, J. E., Moore, S. E., Farley, E. V., Carmack, E. C., Cooper, L. W.,
905 Frey, K.E., Helle, J.H., McLaughlin, F.A., and McNutt, S. L. (2006). A major ecosystem
906 shift in the northern Bering Sea. *Science*, 311(5766), 1461-1464.
907 <https://doi.org/10.1126/science.1121365>

908 Gupta, B. K. S. (1999). *Modern foraminifera* (pp. 7-36). B. K. S. Gupta (Ed.). Dordrecht: Kluwer
909 Academic Publishers.

910 Hald, M., and Korsun, S. (1997). Distribution of modern benthic foraminifera from fjords of
911 Svalbard, European Arctic. *The Journal of Foraminiferal Research*, 27(2), 101-122.
912 <https://doi.org/10.2113/gsjfr.27.2.101>

913 Hammer, Ø., K. Webb, and D. Depreiter. (2009). Numerical simulation of upwelling currents
914 in pockmarks, and data from the Inner Oslofjord, Norway. *Geo Mar. Lett.* 29: 269–275.
915 <https://doi.org/10.1007/s00367-009-0140-z>

916 Hartree, E. F. (1972). Detennination of protein: A modification of the Lowry method. *Anal*
917 *Biochem*, 48-422.

918 Heinz, P., Sommer, S., Pfannkuche, O., and Hemleben, C. (2005). Living benthic foraminifera
919 in sediments influenced by gas hydrates at the Cascadia convergent margin, NE
920 Pacific. *Marine Ecology Progress Series*, 304, 77-89. <https://doi.org/10.3354/meps304077>

921 Jauffrais, T., Lekieffre, C. M. N., Geslin, E., Schweizer, M., Metzger, E., Bernhard, J. M.,
922 Jesus, B., Filipsson, H., Maire O. and Meibom, A. (2018). *Kleptoplastidic benthic*

923 *foraminifera from aphotic habitats: Assimilation (or not) of inorganic C, N, and S*
924 *studied at sub-cellular resolution* (No. POST_TALK).

925 Jernas, P., Klitgaard-Kristensen, D., Husum, K., Koç, N., Tverberg, V., Loubere, P., Prins,
926 M., Dijkstra, N. and Gluchowska, M. (2018). Annual changes in Arctic fjord
927 environment and modern benthic foraminiferal fauna: Evidence from Kongsfjorden,
928 Svalbard. *Global and planetary change*, 163, 119-140.
929 <https://doi.org/10.1016/j.gloplacha.2017.11.013>

930 Jorissen, F. J., de Stigter, H. C., and Widmark, J. G. (1995). A conceptual model explaining
931 benthic foraminiferal microhabitats. *Marine micropaleontology*, 26(1-4), 3-15.
932 [https://doi.org/10.1016/0377-8398\(95\)00047-X](https://doi.org/10.1016/0377-8398(95)00047-X)

933 Koenigk, T., Mikolajewicz, U., Jungclaus, J. H., and Kroll, A. (2009). Sea ice in the Barents
934 Sea: seasonal to interannual variability and climate feedbacks in a global coupled
935 model. *Climate dynamics*, 32(7-8), 1119-1138. [https://doi.org/10.1007/s00382-008-](https://doi.org/10.1007/s00382-008-0450-2)
936 [0450-2](https://doi.org/10.1007/s00382-008-0450-2)

937 Koho, K. A., García, R. D., De Stigter, H. C., Epping, E., Koning, E., Kouwenhoven, T. J., and
938 Van der Zwaan, G. J. (2008). Sedimentary labile organic carbon and pore water redox
939 control on species distribution of benthic foraminifera: A case study from Lisbon–Setúbal
940 Canyon (southern Portugal). *Progress in Oceanography*, 79(1), 55-82.
941 <https://doi.org/10.1016/j.pocean.2008.07.004>

942 Korsun, S. A., Pogodina, I. A., Forman, S. L., and Lubinski, D. J. (1995). Recent foraminifera
943 in glaciomarine sediments from three arctic fjords of Novaja Zemlja and Svalbard. *Polar*
944 *Research*, 14(1), 15-32. <https://doi.org/10.3402/polar.v14i1.6648>

945 Langezaal, A. M., Jorissen, F. J., Braun, B., Chaillou, G., Fontanier, C., Anschutz, P., and Van
946 der Zwaan, G. J. (2006). The influence of seasonal processes on geochemical profiles
947 and foraminiferal assemblages on the outer shelf of the Bay of Biscay. *Continental Shelf*
948 *Research*, 26(15), 1730-1755. <https://doi.org/10.1016/j.csr.2006.05.005>

949 Lantzsch, H., Hanebuth, T. J. J., Horry, J., Grave, M., Rebesco, M., and Schwenk, T. (2017).
950 Deglacial to Holocene history of ice-sheet retreat and bottom current strength on the
951 western Barents Sea shelf. *Quaternary Science Reviews*.
952 <https://doi.org/10.1016/j.quascirev.2017.08.016>

953 Larkin, K. E., and Gooday, A. J. (2004). Soft-shelled monothalamous foraminifera at an
954 intertidal site on the south coast of England. *Journal of Micropalaeontology*, 23(2),
955 135-137. <https://doi.org/10.1144/jm.23.2.135>

956 Licari, L. N., Schumacher, S., Wenzhofer, F., Zabel, M., and Mackensen, A. (2003).
957 Communities and microhabitats of living benthic foraminifera from the tropical east
958 Atlantic: impact of different productivity regimes. *The Journal of Foraminiferal*
959 *Research*, 33(1), 10-31. <https://doi.org/10.2113/0330010>

960 Loeblich, A. R., and Tappan, H. N. (1953). Studies of Arctic foraminifera. *Smithsonian*
961 *Miscellaneous Collections*.

962 Loeng, H. (1991). Features of the physical oceanographic conditions of the Barents
963 Sea. *Polar research*, 10(1), 5-18. <https://doi.org/10.3402/polar.v10i1.6723>

964 Loeng, H., Ozhigin, V., and Ådlandsvik, B. (1997). Water fluxes through the Barents
965 Sea. *ICES Journal of Marine Science*, 54(3), 310-317.
966 <https://doi.org/10.1006/jmsc.1996.0165>

967 Lorenzen, C. J., and Jeffrey, S. W. (1980). Determination of chlorophyll in seawater. *Unesco*
968 *Technical Papers in Marine Science*.

969 Lucchi, R. G., Bazzaro, M., Biebow, N., Carbonara, K., Caridi, F., De Vittor, C., ... and
970 Krueger, M. (2016). BURSTER-Bottom Currents in a Stagnant Environment.
971 EUROFLEETS-2 Cruise Summary Report.

- 972 Majewski, W., PAWŁOWSKI, J., and ZAJĄCZKOWSKI, M. (2005). Monothalamous
973 foraminifera from West Spitsbergen fjords, Svalbard: a brief overview. *Polish Polar*
974 *Research*, 26(4), 269-285.
- 975 Majewski, W., and Zajaczkowski, M. (2007). Benthic foraminifera in Adventfjorden, Svalbard:
976 Last 50 years of local hydrographic changes. *The Journal of Foraminiferal*
977 *Research*, 37(2), 107-124. <https://doi.org/10.2113/gsjfr.37.2.107>
- 978 Marsh, J. B., and Weinstein, D. B. (1966). Simple charring method for determination of lipids.
979 *Journal of Lipid Research*.
- 980 Martins, M. V. A., Pinto, A. F. S., Frontalini, F., da Fonseca, M. C. M., Terroso, D. L., Laut, L.
981 L. M., ... and Rocha, F. (2016). Can benthic foraminifera be used as bio-indicators of
982 pollution in areas with a wide range of physicochemical variability?. *Estuarine, Coastal*
983 *and Shelf Science*, 182, 211-225. <https://doi.org/10.1016/j.ecss.2016.10.011>
- 984 Maslowski, W., Marble, D., Walczowski, W., Schauer, U., Clement, J. L., and Semtner, A. J.
985 (2004). On climatological mass, heat, and salt transports through the Barents Sea
986 and Fram Strait from a pan-Arctic coupled ice-ocean model simulation. *Journal of*
987 *Geophysical Research: Oceans*, 109(C3). <https://doi.org/10.1029/2001JC001039>
- 988 Mityaev, M. V., Pogodina, I. A., and Gerasimova, M. V. (2005). Facies variability of recent
989 sediments in the Hornsunn Fjord, western Spitsbergen. *Lithology and Mineral*
990 *Resources*, 40(5), 401-407.
- 991 Mojtahid, M., Geslin, E., Coynel, A., Gorse, L., Vella, C., Davranche, A., Zozzolo, L., Blanchet,
992 L., Bénétiau, E. and Maillet, G. (2016). Spatial distribution of living (Rose Bengal stained)
993 benthic foraminifera in the Loire estuary (western France). *Journal of Sea Research*, 118,
994 1-16. <https://doi.org/10.1016/j.seares.2016.02.003>
- 995 Murray, J. W. (2006). *Ecology and applications of benthic foraminifera*. Cambridge University
996 Press.
- 997 Onarheim, I. H. and Årthun, M. (2017). Toward an ice-free Barents Sea. *Geophysical*
998 *Research Letters*, 44(16), 8387-8395. <https://doi.org/10.1002/2017GL074304>
- 999 Orvik, K. A., and Niiler, P. (2002). Major pathways of Atlantic water in the northern North
1000 Atlantic and Nordic Seas toward Arctic. *Geophysical Research Letters*, 29(19), 2-1.
1001 <https://doi.org/10.1029/2002GL015002>
- 1002 Padman, L., and Erofeeva, S. (2005). Tide Model Driver (TMD) Manual. *Earth and Space*
1003 *Research*.
- 1004 Pielou, E. C. (1975). *Ecological diversity* (No. 574.524018 P5).
- 1005 Piepenburg, D., and Schmid, M. K. (1996). Distribution, abundance, biomass, and
1006 mineralization potential of the epibenthic megafauna of the Northeast Greenland
1007 shelf. *Marine Biology*, 125(2), 321-332. <https://doi.org/10.1007/BF00346313>
- 1008 Piepenburg, D., and Schmid, M. K. (1997). A photographic survey of the epibenthic
1009 megafauna of the Arctic Laptev Sea shelf: distribution, abundance, and estimates of
1010 biomass and organic carbon demand. *Marine Ecology Progress Series*, 147, 63-75.
1011 <https://doi.org/10.3354/meps147063>
- 1012 Polyak, L., Korsun, S., Febo, L. A., Stanovoy, V., Khusid, T., Hald, M., Paulsen, B.E. and
1013 Lubinski, D. J. (2002). Benthic foraminiferal assemblages from the southern Kara Sea, a
1014 river-influenced Arctic marine environment. *The Journal of Foraminiferal Research*,
1015 32(3), 252-273. <https://doi.org/10.2113/32.3.252>
- 1016 Pucci, F., Geslin, E., Barras, C., Morigi, C., Sabbatini, A., Negri, A., and Jorissen, F. J. (2009).
1017 Survival of benthic foraminifera under hypoxic conditions: Results of an experimental
1018 study using the CellTracker Green method. *Marine Pollution Bulletin*, 59(8-12), 336-351.
1019 <https://doi.org/10.1016/j.marpolbul.2009.08.015>
- 1020 Pusceddu, A., Sarà, G., Armeni, M., Fabiano, M., and Mazzola, A. (1999). Seasonal and
1021 spatial changes in the sediment organic matter of a semi-enclosed marine system (W-
1022 Mediterranean Sea). *Hydrobiologia*. <https://doi.org/10.1023/A:1003690313842>
- 1023 Pusceddu, A., Dell'Anno, A., and Fabiano, M. (2000). Organic matter composition in coastal
1024 sediments at Terra Nova Bay (Ross Sea) during summer 1995. *Polar Biology*.

1025 <https://doi.org/10.1007/s003000050446>

1026 Pusceddu, Antonio, Dell'Anno, A., Fabiano, M., and Danovaro, R. (2009). Quantity and
1027 bioavailability of sediment organic matter as signatures of benthic trophic status. *Marine*
1028 *Ecology Progress Series*. <https://doi.org/10.3354/meps07735>

1029 Pusceddu, Antonio, Bianchelli, S., Canals, M., Sanchez-Vidal, A., Durrieu De Madron, X.,
1030 Heussner, S., Lykousis, V., de Stigter, H., Trincerdi, F. and Danovaro, R. (2010). Organic
1031 matter in sediments of canyons and open slopes of the Portuguese, Catalan, Southern
1032 Adriatic and Cretan Sea margins. *Deep-Sea Research Part I: Oceanographic Research*
1033 *Papers*. <https://doi.org/10.1016/j.dsr.2009.11.008>

1034 Pusceddu, Antonio, Bianchelli, S., Gambi, C., and Danovaro, R. (2011). Assessment of
1035 benthic trophic status of marine coastal ecosystems: Significance of meiofaunal rare
1036 taxa. *Estuarine, Coastal and Shelf Science*. <https://doi.org/10.1016/j.ecss.2011.05.012>

1037 Rasmussen, T. L., and Thomsen, E. (2017). Ecology of deep-sea benthic foraminifera in the
1038 North Atlantic during the last glaciation: Food or temperature control. *Palaeogeography,*
1039 *palaeoclimatology,* *palaeoecology*, 472, 15-32.
1040 <https://doi.org/10.1016/j.palaeo.2017.02.012>

1041 Rebesco, M., Liu, Y., Camerlenghi, A., Winsborrow, M., Laberg, J. S., Caburlotto, A., Diviacco,
1042 P., Accettella, D., Sauli, C., Wardell, N., and Tomini, I. (2011). Deglaciation of the western
1043 margin of the Barents Sea Ice Sheet - A swath bathymetric and sub-bottom seismic study
1044 from the Kveithola Trough. *Marine Geology*.
1045 <https://doi.org/10.1016/j.margeo.2010.10.018>

1046 Rebesco, M., Özmaral, A., Urgeles, R., Accettella, D., Lucchi, R. G., Rütther, D., Winsborrow,
1047 M., Liopart, J., Carbulotto, A., Lantzsch, H., and Hanebuth, T. J. J. (2016). Evolution of a
1048 high-latitude sediment drift inside a glacially-carved trough based on high-resolution
1049 seismic stratigraphy (Kveithola, NW Barents Sea). *Quaternary Science Reviews*.
1050 <https://doi.org/10.1016/j.quascirev.2016.02.007>

1051 Rütther, D. C., Bjarnadóttir, L. R., Juntila, J., Husum, K., Rasmussen, T. L., Lucchi, R. G.
1052 and Andreassen, K.
1053 (2012): Pattern and timing of the northwestern Barents Sea Ice Sheet deglaciation and
1054 indications of episodic Holocene deposition. *Boreas*, 10.1111/j.1502-
1055 3885.2011.00244.x. ISSN 0300-9483.

1056 Sabbatini, A., Morigi, C., Negri, A., and Gooday, A. J. (2007). Distribution and biodiversity of
1057 stained monothalamous foraminifera from Tempelfjord, Svalbard. *The Journal of*
1058 *Foraminiferal Research*, 37(2), 93-106. <https://doi.org/10.2113/gsjfr.37.2.93>

1059 Sabbatini, A., Bonatto, S., Bianchelli, S., Pusceddu, A., Danovaro, R., and Negri, A. (2012).
1060 Foraminiferal assemblages and trophic state in coastal sediments of the Adriatic
1061 Sea. *Journal of Marine Systems*, 105, 163-174.
1062 <https://doi.org/10.1016/j.jmarsys.2012.07.009>

1063 Sabbatini, A., Nardelli, M. P., Morigi, C., and Negri, A. (2013). Contribution of soft-shelled
1064 monothalamous taxa to foraminiferal assemblages in the Adriatic Sea. *Acta*
1065 *Protozoologica*, 52(3). doi:10.4467/16890027AP.13.0016.1113

1066 Saher, M. H., Kristensen, D. K., Hald, M., Korsun, S., and Jørgensen, L. L. (2009). Benthic
1067 foraminifera assemblages in the Central Barents Sea: an evaluation of combining live
1068 and total fauna studies in tracking environmental change. *Norwegian Journal of Geology*,
1069 89 (2009), pp. 149-161

1070 Saher, M., Kristensen, D. K., Hald, M., Pavlova, O., & Jørgensen, L. L. (2012). Changes in
1071 distribution of calcareous benthic foraminifera in the central Barents Sea between the
1072 periods 1965–1992 and 2005–2006. *Global and Planetary Change*, 98, 81-96.
1073 <https://doi.org/10.1016/j.gloplacha.2012.08.006>

1074 Schlitzer, Reiner, Ocean Data View, odv.awi.de, 2020

1075 Schönfeld, J. (2002). A new benthic foraminiferal proxy for near-bottom current velocities in
1076 the Gulf of Cadiz, northeastern Atlantic Ocean. *Deep Sea Research Part I:*
1077 *Oceanographic Research Papers*, 49(10), 1853-1875.

1078 [0637\(02\)00088-2](https://doi.org/10.1016/j.margeo.2016.10.005)
1079 Seidenkrantz, M. S. (1995). *Cassidulina teretis* Tappan and *Cassidulina neoteretis* new
1080 species (Foraminifera): stratigraphic markers for deep sea and outer shelf areas. *Journal*
1081 *of Micropalaeontology*, 14(2), 145-157
1082 Sergeeva, N. G., Anikeeva, O. V., and Gooday, A. J. (2010). Soft-shelled, monothalamous
1083 foraminifera from the oxic/anoxic interface (NW Black Sea). *Micropalaeontology*, 393-407.
1084 Smedsrud, L. H., Esau, I., Ingvaldsen, R. B., Eldevik, T., Haugan, P. M., Li, C., Lien, V.S.,
1085 Olsen, A., Omar, A.M., Otterå, O. H., Risebrobakken, B., Sandø, A. B., Semenov, V. A.
1086 and Sorokina, S. A. (2013). The role of the Barents Sea in the Arctic climate
1087 system. *Reviews of Geophysics*, 51(3), 415-449. <https://doi.org/10.1002/rog.20017>
1088 Van der Zwaan, G. J., Duijnste, I. A. P., Den Dulk, M., Ernst, S. R., Jannink, N. T., and
1089 Kouwenhoven, T. J. (1999). Benthic foraminifers: proxies or problems?: a review of
1090 paleocological concepts. *Earth-Science Reviews*, 46(1-4), 213-236.
1091 [https://doi.org/10.1016/S0012-8252\(99\)00011-2](https://doi.org/10.1016/S0012-8252(99)00011-2)
1092 Vinje, T., and Kvambekk, Å. S. (1991). Barents Sea drift ice characteristics. *Polar*
1093 *Research*, 10(1), 59-68. <https://doi.org/10.1111/j.1751-8369.1991.tb00635.x>
1094 Włodarska-Kowalczyk, M., and Pearson, T. H. (2004). Soft-bottom macrobenthic faunal
1095 associations and factors affecting species distributions in an Arctic glacial fjord
1096 (Kongsfjord, Spitsbergen). *Polar Biology*, 27(3), 155-167.
1097 <https://doi.org/10.1007/s00300-003-0568-y>
1098 Włodarska-Kowalczyk, M., Renaud, P. E., Węśławski, J. M., Cochrane, S. K., and Denisenko,
1099 S. G. (2012). Species diversity, functional complexity and rarity in Arctic fjordic versus
1100 open shelf benthic systems. *Marine Ecology Progress Series*, 463, 73-87.
1101 <https://doi.org/10.3354/meps09858>
1102 Wollenburg, J. E., Mackensen, A., and Kuhnt, W. (2007). Benthic foraminiferal biodiversity
1103 response to a changing Arctic palaeoclimate in the last 24.000 years. *Palaeogeography,*
1104 *Palaeoclimatology,* *Palaeoecology*, 255(3-4), 195-222.
1105 <https://doi.org/10.1016/j.palaeo.2007.05.007>
1106 Yang, X., Zeng, G., Zhang, G., and Li, Z. (2020). Interdecadal Variation of Winter Cold Surge
1107 Path in East Asia and Its Relationship with Arctic Sea Ice. *Journal of Climate*, 33(11),
1108 4907-4925. <https://doi.org/10.1175/JCLI-D-19-0751.1>
1109 Zecchin, M., Rebesco, M., Lucchi, R. G., Caffau, M., Lantzsck, H., and Hanebuth, T. J. (2016).
1110 Buried iceberg-keel scouring on the southern Spitsbergenbanken, NW Barents
1111 Sea. *Marine Geology*, 382, 68-79. <https://doi.org/10.1016/j.margeo.2016.10.005>

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