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1 **Influence of modern environmental gradients on foraminiferal faunas in**
2 **the inner Kongsfjorden (Svalbard)**

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12 **Keywords:** benthic foraminifera, bioindicators, tidewater glacier, Arctic, fjord hydrology

13 **Abstract**

14 The Kongsfjorden, an Arctic fjord located in the north-western Svalbard archipelago, is
15 influenced by the Atlantic Water (AW) inflow from the shelf as well as by tidewater glacier
16 dynamics at the fjord head. This generates strong environmental gradients across the fjord
17 creating high physical and geochemical stress for the benthic faunas. This research focuses
18 on the study of benthic foraminiferal faunas under present-day environmental conditions
19 (during summer 2018) in the inner Kongsfjorden, with the aim at understanding the main
20 environmental factors governing their distribution and species composition. To that aim,
21 surface sediments from 9 stations were sampled during August 2018 following a transect along
22 the main axis of the fjord, from near the front (ca. 2 km) of the tidewater glaciers Kronebreen
23 and to about 12 km seaward. The results show that the distribution of foraminiferal
24 assemblages was influenced by the dual effect of the proximity of the glacier front and the AW
25 inflow and the associated hydrological, sedimentary, and food export processes. These
26 resulted in the succession of three ecological groups along the inner fjord axis, responding to
27 physical disturbances linked to the proximity of the Kronebreen terminus (i.e., high water
28 turbidity, freshwater, and sediment inputs from subglacial discharges). Close to the glacier
29 front, few stress-tolerant and glacier proximal species were present (i.e., *Capsammina*
30 *bowmanni* and *Cassidulina reniforme*). At about 6-8 km from the glacier front, reduced turbidity,
31 and an increase in organic matter fluxes (likely related to an increase in primary production),
32 resulted in a higher foraminiferal diversity, and a high abundance of the phytodetritus-indicator
33 *Nonionellina labradorica*. Relatively high taxonomic diversity persists until 12 km from the
34 glacier front due to higher organic inputs and reduced stressful conditions (i.e., decreasing
35 freshwater and sediment inputs). The outer assemblage was dominated by the AW indicator
36 *Adercotryma glomeratum*, in coherence with the presence of warm and salty AW far inside the
37 Kongsfjorden during the sampling period. Physical stress related to the glacier dynamics
38 appears to favour the establishment of an opportunistic pioneer assemblage close to the
39 terminus, whereas reduced disturbance away from the glacier induces the establishment of

40 diverse foraminiferal assemblages. Based on the strong response of benthic foraminifera on a
41 kilometric scale, they may be effective bioindicators for annual monitoring the long-term retreat
42 of tidewater glaciers as a result of climate change in Kongsfjorden.

43 **1. Introduction**

44 The ongoing climate change is threatening the Arctic region at faster rate compared to lower
45 latitudes (IPCC, 2019). In the last decades, the Arctic warming doubled the global mean, a
46 phenomenon called Arctic amplification (AA - Dai et al., 2019; Holland and Bitz, 2003).
47 Although the exact causes of the AA are still debated, the scientific community agrees that it
48 is mainly the result of both local feedbacks (e.g. ice-albedo - Screen and Simmonds, 2010;
49 Stuecker et al., 2018) and climatic/oceanographic forcing (e.g. changes in poleward heat
50 transport - Graversen et al., 2008; Screen et al., 2012). The rapid sea ice cover shrinking and
51 glacier mass loss is a striking evidence of climate change in the Arctic (IPCC, 2019). The
52 climate change-induced increase in ocean temperature and reduction in water stratification are
53 among the causes of the sea ice decline in the Arctic Ocean (e.g. Lind et al., 2018; Polyakov
54 et al., 2017; Yu et al., 2021). For land-terminating glaciers, the major mechanism for melting is
55 through surface meltwaters migrating to the ice-bedrock interface (e.g. Tedstone et al., 2015;
56 Zwally et al., 2002), whereas ocean-terminating glaciers mainly lose mass through calving at
57 the glacial front by warming seawater temperatures (e.g., Luckman et al., 2015). Whether
58 through rising sea temperatures or changes in freshwater and sediment inputs induced by
59 glacier melting, these climate change-induced phenomena are having, and will continue to
60 have, several implications for Arctic marine ecosystems, with repercussions on the benthic and
61 pelagic realms (Meredith et al., 2019).

62 The Svalbard archipelago (74-81°N and 10-35°E) is largely influenced by the warm and
63 saline Atlantic Water (AW). The AW, carried by the North Atlantic Current (NAC) and further
64 north by the West Spitsbergen Current (WSC), flows west of the archipelago and enters the
65 Arctic Ocean as the major source of heat, carbon, and plankton (e.g., Vernet et al., 2019) (Fig.

66 1). Western Svalbard fjords, located close to the WSC path, experience an increasing influence
67 of warm and saline AW, more than any other Arctic fjords (Cottier et al., 2007; Saloranta and
68 Svendsen, 2001). Furthermore, the mean temperature of the WSC core (20-200 m depth) has
69 increased by 0.7°C in the last 20 years (Norwegian Polar Institute, 2021). Beside the climatic
70 modifications, the hydrological conditions of the fjord are also subjected to extreme seasonal
71 variations. During summer, warm AW incursions and freshwater inputs from glaciers,
72 determine the presence of strong temperature and salinity gradients across these systems
73 (e.g. Cottier et al., 2010; Hop et al., 2002; Hop and Wiencke, 2019; Svendsen et al., 2002).
74 The fjords, through circulation dynamics and mixing between fjord and shelf waters (i.e. an
75 inshore dominated by glaciers with seasonal meltwater inputs and an offshore influenced by
76 warm oceanic water intrusions), represent a link between the ocean and the land (Cottier et
77 al., 2010). Therefore, these systems are submitted to combined variations of these two end-
78 members and are thus sensitive to seasonal climatic fluctuations and to oceanographic
79 changes (Cottier et al., 2005).

80 The Kongsfjorden, a glacially, over-deepened valley located in the north-western coast of
81 Spitsbergen, is influenced by the AW circulation as well as by tidewater glacier dynamics and
82 the associated water masses at the fjord head (Hop et al., 2002; Sundfjord et al., 2017;
83 Svendsen et al., 2002). Nowadays, this fjord is experiencing important changes. Before 2006,
84 extensive sea ice was formed each winter in the inner fjord, but since then, the increased inflow
85 of AW and the resulting overall increasing trend in seawater temperatures (e.g., Cottier et al.,
86 2007; David T and K.P., 2017; Payne and Roesler, 2019; Tverberg et al., 2019) shifted the
87 fjord system into a warmer state (Cottier et al., 2010, 2007). This resulted in a reduced sea ice
88 cover (i.e., up to 50% decrease; Pavlova et al., 2019) and thickness (i.e., from 0.6 m to 0.2 m
89 decrease; Pavlova et al., 2019).

90 In summer, it has been reported that AW intrusion in the Kongsfjorden occurred during
91 prolonged periods of time, and that AW has reached the inner part of the fjord only in the last
92 decade (Holmes et al., 2019). This recent hydrological change strongly enhanced submarine
93 melt and calving (i.e., frontal ablation) of tidewater glaciers (Holmes et al., 2019; Luckman et

94 al., 2015), and consequently increased meltwater discharges and associated sediment load at
95 the fjord head. As a result, the higher water turbidity in the vicinity of the marine termini of
96 Kronebreen and Kongsvegen glaciers reduces local euphotic depth, disrupting phytoplankton
97 distribution and biomass at the Kongsfjorden head (Payne and Roesler, 2019). Furthermore,
98 glacial meltwater runoff has a direct implication in building up steep temperature and salinity
99 vertical gradients that lead to stable water stratification in the fjord. As a consequence primary
100 production is even more affected with repercussions on the entire trophic chain (Pasculli et al.,
101 2020). Knowing that marine-terminating glaciers generally sustain high productivity in arctic
102 fjords (Meire et al., 2017), the recent seasonal processes developing in the Kongsfjorden may
103 cause persistent physical and geochemical stresses with impact on the fjord ecosystem,
104 particularly on the benthic faunas.

105 The impact of increasing glacial melting on the Arctic marine ecosystems remains poorly
106 studied (Meire et al., 2017), and a better understanding of the resilience capability of fjord
107 ecosystems under present-day evolving conditions is needed (Hop et al., 2019). To that aim,
108 benthic foraminifera are powerful and promising tools. Thanks to their short life cycle and
109 specific ecological requirements, they respond quickly to environmental disturbance (e.g.,
110 Jorissen et al., 1995; Hald and Korsun, 1997; Alve et al., 2016; Jernas et al., 2018). Moreover,
111 their fossilisation potential allows historical and paleoenvironmental reconstructions (e.g.,
112 Skirbekk et al., 2010; Jernas et al., 2013; Pawłowska et al., 2017) providing critical information
113 on the evolution of a similar habitat in the recent past (e.g., tens to hundreds of years).

114 The present study focuses on the ecology of benthic foraminiferal faunas under current
115 environmental conditions in the inner Kongsfjorden, with the aim of understanding the main
116 drivers of benthic communities in fjords influenced by glacier dynamics and in a warm state.
117 Foraminiferal distribution was analysed in response to the steep environmental gradients
118 created by the meltwater runoff from tidewater glaciers at the fjord head and the AW inflow at
119 the fjord mouth in summer.

120 **2. Study area**

121 **2.1. Geographical and geological setting**

122 The Kongsfjorden is a glaciomarine fjord (20 km long and 4-10 km wide) located on the north
123 western coast of Spitsbergen (79°N, 12° E) in the Svalbard archipelago. This fjord, elongated
124 in the SE-NW direction, is located on a tectonic boundary between the Tertiary Fold and Thrust
125 Belt to the south-west thrusting on the Northwestern Basement Province to the north-east
126 (Bergh et al., 2000). The Kongsfjorden has likely developed in a morphological depression
127 linked to fractures of the bedrock, parallel to the thrust front (Husum et al., 2019; Svendsen et
128 al., 2002).

129 Bedrocks of different composition are present in the fjord basement (Svendsen et al. 2002).
130 Located on the Northwestern Basement Province, the northern bank of the fjord consists of
131 medium-grade metamorphic (Middle Proterozoic age) marbles, mica-schists, and quartzites.
132 The eastern part of the fjord and the islands at the fjord head (e.g., Blomstandhalvøya; Fig.1)
133 are composed of slices of unmetamorphosed rocks (red conglomerates and sandstones) of
134 Devonian age and marbles. Above the basal Tertiary thrust, the southern Kongsfjorden
135 bedrock consists of sedimentary rocks of Late Palaeozoic and Tertiary Age, with some
136 Proterozoic low- and medium-grade metamorphic rocks (mica-schists, marbles, phyllites,
137 quartzites) (Svendsen et al., 2002).

138 The main source of sediment in Kongsfjorden is through subglacial discharge from tidewater
139 glaciers (Svendsen et al., 2002; Trusel et al., 2010; D'Angelo et al., 2018). In addition, the
140 glacial rivers of the Lovenbreen continental glaciers can provide a further supply of sediment
141 (Bourriquen et al., 2016; 2018). Particles flux into the Kongsfjorden mainly consist of
142 siliciclastic and detrital carbonate grains (D'Angelo et al., 2018). The bedrock geology of glacier
143 catchments also influences the nutrient dynamics in the fjord. The sedimentary supply derived
144 from the erosion of the surrounding bedrocks, that nourishes the Kongsfjorden waters through
145 meltwater discharge, makes this environment rich in silicon (e.g., silica-rich bedrock

146 determines high silicic acid content in glacier meltwaters; Halbach et al., 2019) and iron
147 (Laufer-Meiser et al., 2021). Limitation of sea life will come from a deficit of fresh organic matter
148 with low C:N ratio (Laufer-Meiser et al., 2021). At the fjord head, high accumulation rates of
149 detrital material (i.e., 6-8 cm yr⁻¹; Zaborska et al., 2006; Trusel et al., 2010) and low primary
150 productivity lead to bottom sediments with low total organic carbon (TOC) content, as a result
151 of the dilution effect of lithogenic material. Laufer-Meiser et al. (2021) found organic carbon
152 with a very high C:N ratio (i.e., ratio of up to 70) in sediment close to the glacial source,
153 originating from the terrestrial input of refractory petrogenic organic carbon (more resistant to
154 microbial degradation compared to fresh marine organic carbon, Arndt et al., 2013)

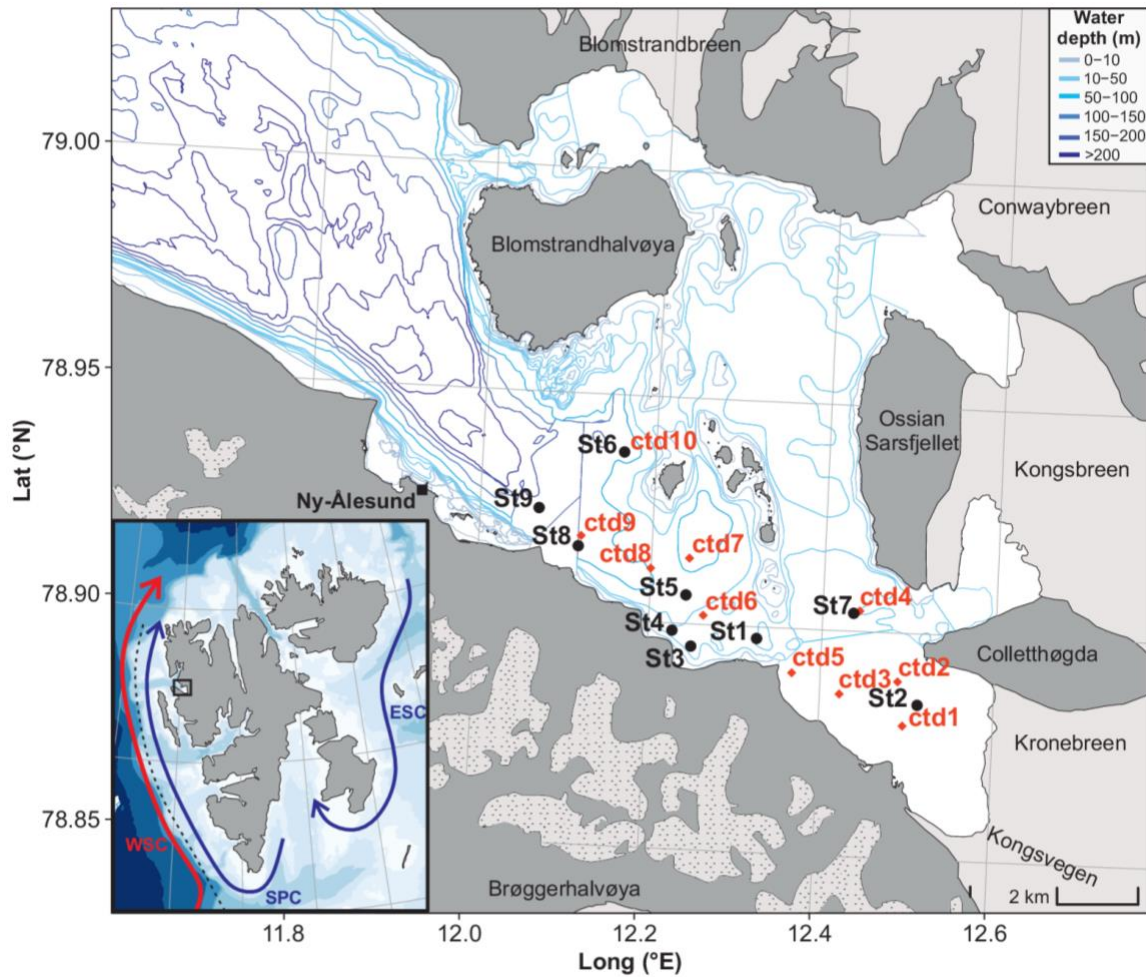
155 **2.2. Oceanographic and hydrological setting**

156 The Svalbard archipelago (74-81°N and 10-35°E) is the eastern margin of the Fram Strait that
157 connects the Atlantic and Arctic Oceans. Active exchanges between northern-sourced and
158 southern-sourced water masses, that are essential for modulating the climate at various time-
159 scales occur through this gateway (Dickson et al. 2008). The Fram Strait channels the inflow
160 of the dominant heat source for the Arctic Ocean, the Atlantic Water (AW), via the West
161 Spitsbergen Current (WSC), a branch of the North Atlantic Current (Schauer et al., 2004). On
162 the western margin of Svalbard, the WSC flows northwards along the continental slope
163 whereas the Spitsbergen Polar Current (SPC), an extension of the East Spitsbergen Current
164 (ESC), transport Arctic Water (ArW) parallel on the continental shelf of Spitzbergen (Tverberg
165 et al., 2019) (Fig. 1). Cold and fresh ArW carried by SPC is separated from the warm and
166 saline AW by the Arctic front (Fig. 1).

167 The Kongsfjorden, due to its geographical location on the western margin of Svalbard, and
168 its open fjord configuration, i.e. without a well-defined sill (Howe et al. 2003), is strongly
169 influenced by oceanic intrusion derived from the Fram Strait circulation and depending on the
170 Arctic front dynamics (Svendsen et al., 2002). Water mass intrusions across this front are
171 allowed by barotropic instabilities (Saloranta and Svendsen, 2001). Frontal instabilities, due to

172 strong northerly winds, promote the AW upwelling from the WSC core and thus, the AW
173 advection across the shelf into the Kongsfjorden (Cottier et al., 2005, 2007; Svendsen et al.,
174 2002). However, the AW intrusions occur especially in summer when there is a geostrophic
175 balance between shelf and fjord waters (Svendsen et al., 2002; Cottier et al., 2005). These
176 cross-shelf mechanisms determine a seasonal shift between the prevailing cold and fresh ArW
177 during winter, and the warm and saline AW during summer on the shelf and into the fjord
178 (Svendsen et al., 2002; Cottier et al., 2005).

179 The spreading of AW intrusion into the fjord changes yearly, determining the distinction
180 between “cold” and “warm” years (Cottier et al., 2005; Hop et al., 2002; Svendsen et al., 2002).
181 Cottier et al. (2005) hypothesised that this interannual variability depends on both internal and
182 external factors. The internal parameter would be the formation of sea ice during the preceding
183 winter, whereas the external factor is most likely the shelf wind field creating instabilities at the
184 shelf front during summer.



185

186 **Figure 1.** Map of the Kongsfjorden showing, on the eastern and northern bank, the five tidewater
 187 glaciers flowing in the fjord (light grey) and on the southern bank the continental (land terminating)
 188 glaciers (dotted light grey). The nine stations sampled with the interface corer (black dots), the ten
 189 locations of CTD cats (red squares) performed during August 2018. On the bottom left of the panel, a
 190 map of Svalbard archipelago showing the main current streams: Arctic waters (blue lines) carried by the
 191 East Spitsbergen Current (ESC) and Spitsbergen Polar Current (SPC), and Atlantic waters transported
 192 by the West Spitsbergen Current (WSC). The dashed black line represents the Arctic front west of
 193 Spitsbergen. The map was performed with the R package PlotSvalbard (Vihtakari, 2020).

194 The Kongsfjorden is surrounded by four continental (land-terminating) glaciers (Estre
 195 Lovenbreen, Midtre Lovenbreen, Westre Lovenbreen, and Pedersenbreen) and five tidewater
 196 (marine-terminating) glaciers (Blomstrandbreen, Conwaybreen, Kongsbreen, Kronebreen and
 197 Kongsvegen; Fig. 1). During summer, those tidewater glaciers highly contribute to the fjord
 198 dynamics with important freshwater and sediment inputs. Kronebreen, a fast-flowing tidewater

199 glacier, has one of the highest flux rates in Svalbard (winter speed of 1.5-2 m d⁻¹, with 3-4 m
200 d⁻¹ peaks in summer; Luckman et al., 2015).

201 Due to the dual influence of AW inflow and freshwater inputs from glacier meltwaters, the
202 Kongsfjorden is characterised by different seasonal water masses. Cottier et al. (2005) revised
203 the classification of these water masses based on Svendsen et al. (2002). Most of the AW
204 entering the fjord mixes with ArW on the shelf forming the Transformed Atlantic Water (TAW).

205 During late spring and summer, within the fjord, the Surface Water (SW) forms from glacial
206 meltwaters and this layer can mix with the underlying AW or TAW, forming the Intermediate
207 Water (IW). During autumn and winter, surface water cooling leads to the formation of the
208 Local Water (LW). Sea ice formations and consequent brine releases form cold and dense
209 Winter Cooled Water (WCW). During spring and early summer, LW and WCW progressively
210 warm up and decrease in salinity and so are merged in the IW.

211 Most of the freshwater inputs into the fjord come from glacier runoff with the major
212 contribution coming from the fjord head (i.e., Kronebreen and Kongsvegen glaciers; Pramanik
213 et al., 2018). Glacier meltwater exits from the bottom of the terminus through subglacial
214 channels forming a buoyant turbulent plume (How et al., 2017). Subglacial runoff and
215 consequent upwelling of meltwater plumes in front of the tidewater glacier front generate a
216 strong surface outflow and consequent sub-surface inflow of warm and saline AW that
217 promotes submarine melting at the glacier front (Cowton et al., 2015; Sundfjord et al., 2017).
218 It was indeed observed that frontal ablation of tidewater glaciers is primarily controlled by warm
219 sub-surface waters (Holmes et al., 2019; Luckman et al., 2015). During summer, the
220 Kronebreen glacier is a main source of meltwaters and suspended particles which consists in
221 a typical glacial upwelling system; this source forms a plume of fresh and turbid meltwaters
222 spreading in the inner part of the fjord (Meslard et al., 2018). The contribution of continental
223 glaciers to the freshwater inputs is not yet fully understood, but the changes observed in the
224 drainage rivers network from the Lovenbreen glaciers (Bourriquen et al., 2018) reveal their
225 important impact related to the glacier retreat.

226 **2.3. Productivity and organic matter export in the Kongsfjorden**

227 In Arctic environments, phytoplanktonic blooms are limited by light availability and sea ice
228 cover. Spring blooms occur after sea ice break-up and consequent light availability increase,
229 but their timing and intensity can change yearly (Hegseth and Tverberg, 2013; Hodal et al.,
230 2012). Also, changes in community structure in relation to water mass advection from the Fram
231 Strait into the fjord were observed for phytoplankton (Hegseth and Tverberg, 2013; Hodal et
232 al., 2012; Lalande et al., 2016; Piquet et al., 2014). During spring, export fluxes of biogenic
233 matter (phytoplankton) are controlled by zooplankton grazing and sink processes (Lalande et
234 al., 2016).

235 In the summer season, freshwater inputs from land-terminating glaciers do not seem to
236 affect the euphotic depth, whereas meltwater discharges from marine-terminating glaciers
237 have demonstrated a negative impact on the light penetration depth (Payne and Roesler,
238 2019). Meltwater plumes scatter high quantity of suspended matter away from the glacier front
239 which hampers primary productivity (Hopwood et al., 2020) and increases benthic deposition
240 processes via flocculation at the glacier fronts (Halbach et al., 2019; Payne and Roesler, 2019).

241 Although export fluxes of matter are reduced to high input of inorganic particles from
242 glaciers particularly in the innermost part of the fjord (Lalande et al., 2016), meltwater turbid
243 plumes have a fundamental role in fjord ecosystems. Surface waters are continuously supplied
244 by meltwater at the tidewater glacier fronts and are pushed away from the coast and replaced
245 by intermediate water rich in plankton and nutrients from the outer fjord (Lydersen et al., 2014).
246 This upwelling system promotes the formation of foraging area (for seabirds and marine
247 mammals) identified as “ecological hotspots” (Lydersen et al., 2014). Furthermore, water
248 masses advected from the shelf carry Arctic and Atlantic faunas (Basedow et al., 2004; Willis
249 et al., 2006), influencing fjord’s biodiversity.

250 3. Material and methods

251 3.1 Environmental parameters

252 3.1.1 CTD (conductivity-temperature-depth) profiles

253 In August 2018, several water column casts were performed with a conductivity-
254 temperature-depth sensor (CTD profiler, Saiv SD204) equipped with a fluorometer. We
255 selected ten CTD casts (Table 1) close to the sediment sampling stations (see Fig. 2a) to
256 determine water masses characteristics at the sampling time.

257 The Ocean Data View software V.5.3.0 (ODV, Schlitzer, 2020) was used to produce
258 temperature and salinity plots. Mean surface turbidity was calculated considering the
259 uppermost 20 m of the surface column, then an interpolation plot was performed with inverse
260 distance weighted interpolation using the function *interpolate_spatial* in the R package
261 PlotSvalbard (Vihtakari, 2020).

Station	Transect line	Sampling date	Latitude (N)	Longitude (E)	Max depth (m)
CTD1	Proximal	21/08/2018	78°52.769'	12°29.809'	72.3
CTD2	Proximal	21/08/2018	78°53.353'	12°29.368'	67.9
CTD3	Proximal	21/08/2018	78°53.159'	12°25.378'	85
CTD4	Proximal	23/08/2018	78°53.413'	12°25.045'	38.7
CTD5	Proximal	21/08/2018	78°54.272'	12°26.560'	64
CTD6	Medial	21/08/2018	78°54.122'	12°15.771'	33.8
CTD7	Medial	21/08/2018	78°54.873'	12°14.641'	104
CTD8	Medial	21/08/2018	78°54.717'	12°11.992'	86.3
CTD9	Distal	21/08/2018	78°55.104'	12°7.082'	138
CTD10	Distal	21/08/2018	78°56.221'	12°9.760'	142

262 **Table 1.** Sampling date and degrees decimal minutes coordinates of the ten CTD cast location during
263 the ISMOGLAC mission.

264 3.1.2 Sediment sampling

265 In the frame of the IPEV field campaign C3 (Coasts under Climat Change suite) organised
266 in August 2018, within a collaboration with the Aztec Lady sailing boat, the KING18 mission
267 allowed to sample nine stations along a SE-NW transect in the Kongsfjorden, from about 2 km
268 to 12 km off the Kronebreen and Kongsvegen tidewater glacier fronts (Table 2, Fig. 1). The
269 order of the stations is reported based on the distance from the glacier front, determining three

270 zone along the studied transect, i.e. proximal stations close to the glacier front margin, medial
 271 stations located in a ~75m-deep sub-basin (enclosed in shoals and small islands), and distal
 272 stations, at the fjord trench head, deeper than 100 meters. The sediment-water interface was
 273 properly sampled by use of a GeMAX corer that collected two twin sediment cores (9 cm inner
 274 diameter) at each station: the first for grain size and organic matter analyses and the second
 275 for foraminiferal analyses.

Station	Transect line	Sampling date	Latitude (N)	Longitude (E)	Sampling depth (m)	Distance from the front (km)
St2	Proximal	21/08/2018	78°53.053'	12°30.780'	49	1.92
St7	Proximal	22/08/2018	78°54.239'	12°26.142'	68	4.53
St1	Medial	21/08/2018	78°53.847'	12°19.520'	52	6.22
St3	Medial	21/08/2018	78°53.705'	12°15.006'	38	7.68
St4	Medial	22/08/2018	78°53.905'	12°13.657'	35.5	8.25
St5	Medial	22/08/2018	78°54.382'	12°14.511'	75.7	8.25
St8	Distal	22/08/2018	78°54.966'	12°06.917'	114	11.18
St6	Distal	22/08/2018	78°56.241'	12°09.806'	148	11.43
St9	Distal	22/08/2018	78°55.447'	12°04.086'	156	12.47

276 **Table 2.** Location along the transect, sampling date, degrees decimal minutes coordinates, sampling
 277 water depth and distance from the glacier front of the nine stations sampled during the KING18 mission.

278 3.1.3 Sediment grain size and carbon analysis

279 At each station, one core was sliced on board, collecting seven sediment layers (every 0.5
 280 cm between 0 and 2 cm and every 1 cm from 2 down to 5 cm depth, i.e., 0–0.5, 0.5–1, 1–1.5,
 281 1.5–2, 2–3, 3–4 and 4–5 cm), then stored at +4°C. In the laboratory, an aliquot of each slice was
 282 used for grain size analyses and the rest was lyophilised for carbon analyses. The laser
 283 diffraction particle size analyser Malvern Mastersizer 3000 was used to obtain grain size data.
 284 The particle size distributions were analysed with GRADISTAT 8.0 software program (Blott
 285 and Pye, 2001).

286 The carbon analysis was performed using a TOC-V_{CPH} analyser. This instrument measures
 287 the free CO₂ gas released by the combustion of the carbon contained in the sediment sample

288 using a non-dispersive infrared system (NDIR). The total carbon (TC) and total inorganic
289 carbon (TIC) contents were determined on three pseudo-replicates and their values were
290 calculated based on two calibration curves using two standards (glucose for TC and sodium
291 bicarbonate for TIC). The combustion at 900°C of 100 mg of sediment has been used to
292 determine the TC. The combustion at 200°C of 100 mg of sediment was conducted after the
293 addition of 450 µl of concentrate phosphoric acid to determine the TIC. The total organic carbon
294 (TOC) was then calculated indirectly as the difference between the TC and the TIC (Bisutti et
295 al., 2004).

296 *3.1.4 Correlation among environmental variables*

297 Pearson correlations and two sided test between environmental variables were calculated
298 and illustrated using the *ggpairs* function in the R package *GGally* (Schloerke et al., 2021). The
299 correlations were tested for sediment-related properties measured in the 0-0.5 cm sediment
300 layer (i.e., percentage of total carbon (TC), percentage of total inorganic carbon (TIC),
301 percentage of total organic carbon (TOC), percentage of sand, silt and clay), sampling water
302 depth (expressed in meters), extrapolated mean surface water turbidity (0-20 m, expressed in
303 FTU), and distance from the glacier front (expressed in kilometers).

304 Mean surface water turbidity was extrapolated for sediment sampling coordinates
305 performing inverse distance weighted interpolation on CTD cast measurements using the
306 function *interpolate_spatial* in the R package *PlotSvalbard* (Vihtakari, 2020).

307 The distance of each sampling station from the front of the glacier was calculate as follow.
308 We used the satellite image taken on the 1st of August 2018 by LANDSAT7 and LANDSAT8
309 (<https://landsatlook.usgs.gov>) as a reference for the position of the Kronebreen glacier front at

310 the sampling time. Then, the reference point for the front position was selected along the
311 centre-line of the glacier (calculated using the box method; Lea et al., 2014) and its coordinates
312 (i.e., 78°52'39.19"N, 12°35'42.51"E) were obtained using the Google Earth Pro software V
313 7.3.3.7786 (<https://www.google.com/earth/index.html>) after overlying the satellite image. The
314 distances between the reference point and the individual sampling stations were calculated
315 using the *distm* and *distGeo* functions in the R package *geosphere* (Hijmans, 2019).

316 **3.2 Foraminiferal analyses**

317 *3.2.1 Sample processing*

318 Immediately after recovery, the interface cores were sliced horizontally as for the
319 sedimentary analysis (every 0.5 cm between 0 and 2 cm and every 1 cm from 2 down to 5 cm
320 depth, i.e. 0–0.5, 0.5–1, 1–1.5, 1.5–2, 2–3, 3–4 and 4–5 cm). Following the FOBIMO
321 recommendations (Schönfeld et al., 2012), each sample was stored in a 500 cm³ bottle filled
322 with 95% ethanol with 2 g.L⁻¹ of rose bengal stain (to label living foraminifera). In the laboratory,
323 sediment samples were sieved through 63 and 150 µm meshes, then stored in 95% ethanol.
324 All living (rose bengal-stained) specimens of the >150 µm fraction were hand-picked in water
325 for each sediment layer. The small fraction 63–150 µm was considered to investigate potential
326 supplementary ecological information (i.e., presence of juveniles, elongated and/or small sized
327 species), knowing that high densities of small sized foraminifera are common in foraminiferal
328 studies (e.g., Duchemin et al., 2007; Shepherd et al., 2007; Gooday and Goineau, 2019;
329 Fossile et al., 2020). However, being extremely time-consuming, the picking of the living
330 foraminifera from the 63–150 µm size fraction was restricted to the uppermost centimetre of

331 the sediment. Due to high foraminiferal abundances, some samples of the small fraction were
332 dried at 50°C, split with an Otto Microsplitter and hand-sorted to reach a minimum of 300
333 individuals from a whole subsample, then standardised to the entire sample.

334 The presence of fragments of living and dead specimens of two large tubular agglutinated
335 species (*Hyperammina* sp. and *Archimerismus subnodosus*) was documented in some
336 samples (St5, St6, St8 and St9). However, due to the fragility of their test and impossibility to
337 determine the number of individuals represented by the observed fragments, they were not
338 included in the quantitative analysis (e.g., Duros et al., 2013; Cauille et al., 2014). Scanning
339 electron micrographs (SEM) of the major agglutinated and calcareous species are shown in
340 Plate 1 and Plate 2, respectively. *Cassidulina* spp. and *Islandiella* spp. SEM and
341 stereomicroscope pictures are displayed in Figure S4.

342 The dead assemblages from 4-5 cm were picked and analysed to highlight possible
343 differences between living and dead assemblages due to seasonal variability. To do so, the
344 $L/(L+D)$ ratios ($\%Living / (\%Living + \%Dead)$); (Jorissen et al., 1998) were calculated
345 considering the living assemblages from the 0-5 cm core top interval (merging the seven
346 sediment layers) and the dead assemblages from the 4-5 cm sediment layer, for all species >
347 5% in either living or dead assemblages. A ratio ranging between 0 and 0.5 indicates that a
348 species is relatively more abundant in the dead fauna, whereas a species is more abundant in
349 the living assemblage when the ratio ranges between 0.5 and 1. A species is equally abundant
350 in the living and dead assemblages when the ratio is 0.5. As it was not possible to calculate
351 the accumulation rates at our sampling stations, we cannot ascertain whether the 4-5 cm layer
352 a good representation of the thaphonomic loss. Therefore, the $L/(L+D)$ ratios were only used

353 to have a qualitative information on possible seasonal sampling bias. A ratio of 0.5 indicates
354 that there is no discrepancy between the relative abundance of the given species sampled
355 alive in August 2018 and its production all year along. Higher or lower ratios suggest that the
356 sampling time (i.e., August 2018) is not representative of the given species life cycle.

357 3.2.2 Diversity metrics and multivariate analysis

358 Taxonomic diversity was estimated using three different metrics using R package *vegan*
359 (Oksanen, 2019):

- 360 1. Species richness (S; i.e., number of species);
- 361 2. Shannon–Wiener Index (H') calculated as:

$$H' = - \sum_{i=1}^S p_i \ln p_i \quad (\text{i})$$

362 where p_i is the proportion of each species i in the community;

- 363 3. Pielou's evenness (J) calculated as:

$$J = \frac{H'}{\ln S} \quad (\text{ii})$$

364

365 All multivariate analyses were performed using the R software (v. 4.0.0; R Core Team,
366 2020). Hierarchical clustering analyses were performed on relative abundances considering
367 the 0-5 cm sediment layer and the >150 μm size fraction (Bray-Curtis dissimilarity measure).
368 The cluster on stations (complete linkage method) was performed on foraminiferal densities
369 considering all the species, whereas the cluster on the species (average linkage method) used
370 only the densities of the major species (relative abundance >5%). Dissimilarity matrices were

371 calculated using the *vegdist* function in the R package *vegan* (Oksanen, 2019). Different
372 linkage methods were compared among each other and cophenetic distances were computed
373 to assess clustering consistency. Dendrograms were produced with *fviz_dend* function in the
374 R package *factoextra* (Kassambara and Mundt, 2020).

375 Transformation-based redundancy analysis (tb-RDA) was performed on living foraminiferal
376 community considering the 0-5 cm sediment layer and the >150 μm size fraction in relation to
377 environmental parameters. Forward selection was performed on several environmental
378 variables (bottom water depth, TOC, sand, silt, clay percentages and surface water turbidity)
379 and only three parameters were retained (i.e., turbidity and depth, $p < 0.05$; TOC, $p < 0.1$). The
380 significance of the model and ordination axes was tested with the *anova.cca* function in the R
381 package *vegan* (Oksanen, 2019), applying Bonferroni correction. Hellinger transformation was
382 applied to foraminiferal densities, whereas environmental variables were centred and scaled.
383 Both transformations were performed using the *decostand* function in the R package *vegan*
384 (Oksanen, 2019). Adjusted R^2 was calculated to determine the model fit.

385 Differences between the two size fractions (63-150 μm and >150 μm) in the 0-1 cm
386 sediment layer were investigated with a non-metric multidimensional scaling analysis (nMDS).
387 The analysis was performed on foraminiferal densities using the *metaMDS* function (which
388 applied square root transformation and wisconsin double standardisation) in the R package
389 *vegan* (Oksanen, 2019) using Bray-Curtis dissimilarity. A similarity of percentages (SIMPER)
390 analysis was performed using the *simper* function in R package *vegan* (Oksanen, 2019) to
391 investigate the relative contribution of each species to the difference between size fractions.

392 The most influential species (i.e., $p < 0.01$ and average contribution $> 5\%$) were extracted and
393 displayed on the nMDS biplot.

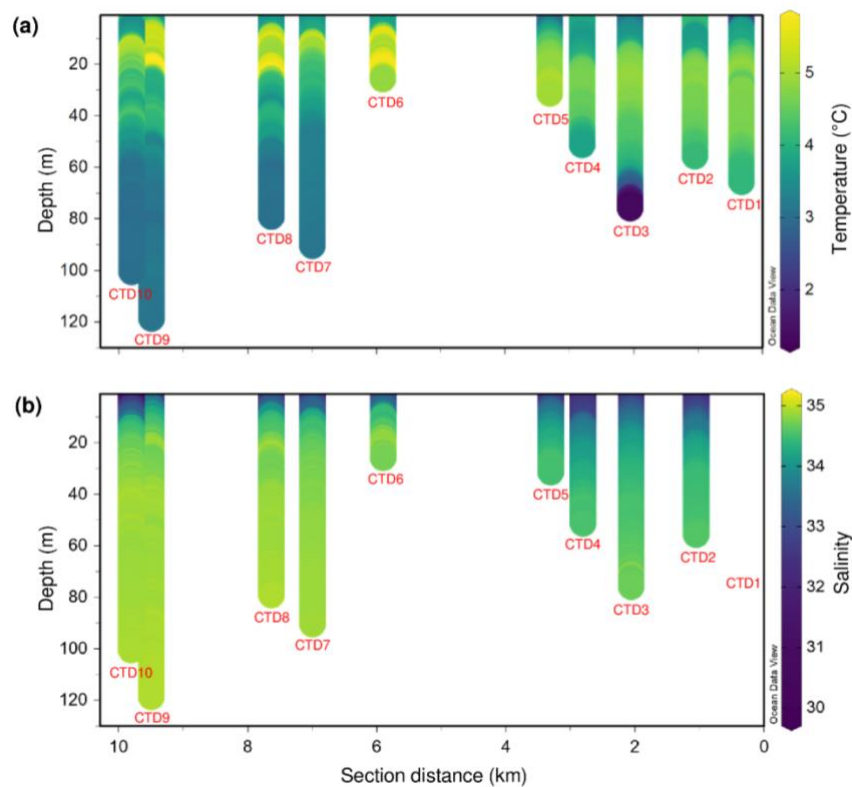
394 **4. Results**

395 **4.1 Environmental parameters**

396 *4.1.1 Water properties*

397 During August 2018, a water stratification was well established in the Kongsfjorden (Fig. 2). All
398 over the inner fjord, the uppermost 10 m of the water column were relatively fresh (salinity
399 range = 30.0 - 34.0) with a narrow temperature range between 3.5 and 4.0°C. This upper layer
400 can be defined as Surface Water (SW, $T > 1^\circ\text{C}$ and $S < 34.0$; Cottier et al., 2005) supplied by
401 intense ice melting during summer. In the 4-10 km section of the sampling transect, waters
402 with the highest temperature, between 4.5 and 5.5°C, and a narrow salinity range ($S = 34.7$ -
403 34.9) were detected below the Surface Water. This relatively warm and saline water mass
404 extending from 10 m to about 30 m water depth was less distinguishable in the innermost part
405 of the fjord. It can be identified as Atlantic Water (AW, $T > 3^\circ\text{C}$ and $S > 34.65$; Cottier et al., 2005)
406 intruding into the fjord up to at least 4 km from the Kronebreen-Kongsvegen glacial front. Below
407 50m depth in 4-10 km section of the transect, the homogeneous water column ($T = 3$ -4°C,
408 $S = 34.7$ -34.9) can be described as Intermediate Water (IW, $T > 1^\circ\text{C}$ and $34.00 < S < 34.65$; Cottier
409 et al., 2005) resulting from the year round mixing of the AW with the SW. In the innermost part
410 of the fjord (0-4 km of the section transect), a cold layer of 1.5 to 3.0°C appeared at the bottom,
411 likely issued from subglacial discharges flowing at the glacier front. The water stratification

412 observed in the Kongsfjorden in August 2018, due to freshwater input from glacial melting and
 413 AW inflow, is typical of the summer season (as described by Svendsen et al., 2002).
 414 The surface water turbidity (average of the 0-20 m layer) displayed values above 80 FTU in
 415 front of the Kronebreen-Kongsvegen terminus and below 20 FTU in all stations located close
 416 to the southern coast or far away from the glacier front (Fig. S1).
 417



418
 419 **Figure 2.** SE-NW 0-130 m deep sections across the Kongsfjorden of the 10 CTD casts for temperature
 420 (°C) **(a)** and salinity **(b)**. Salinity data for CTD1 are not available.

421 **4.1.2 Grain size analyses**

422 Sediments, at all stations and both surficial (0-0.5 cm) and intermediate (2-3 cm) levels, were
 423 medium silts with mean grain sizes ranging from 6.3 to 16.3 μm (Table S1). Grain size curves
 424 mainly showed unimodal distribution with a single mode around 7-9 μm , except at the 2-3 cm
 425 level from two stations (St2 and St8) where a second mode picks at 37.7 and 62.9 μm

426 respectively, indicating a mixture with a population of coarse silts. At all stations, the mean
 427 values slightly increased with depth, a trend more obvious at St2 and St8 (coherent with the
 428 bimodal distribution mentioned above), and at the two shallowest stations close to the southern
 429 coast of the fjord (St3 and St4) where the single mode reached 17.5 and 22.6 μm , respectively.
 430 At all stations, the percentage of sand ($>63 \mu\text{m}$) remained low, about or below 10%, except at
 431 depth at St8 where it reached almost 20% (coherent with the secondary mode of the grainsize
 432 distribution at 62.9 μm). The percentage of clay ($<2 \mu\text{m}$) was everywhere slightly higher in the
 433 surficial sediments and ranging from around 10 to 18%.

434 4.1.3 Organic matter analysis

435 All the sampled stations were characterised by total carbon contents (TC%) between 2.68 and
 436 3.10% in the surface sediment layer (0-0.5 cm) (Table 4). TC was mostly composed of
 437 inorganic carbon (TIC%; values between 2.07 and 2.65 %). Therefore, the total organic carbon
 438 content (TOC%) of the fjord showed values below 0.70% at all stations (Table 3). In general,
 439 TOC percentages were lower close to the terminus in the innermost fjord (St2, St7 and St1
 440 $<0.40\%$) than at downstream stations (between 0.40 and 0.70%). TOC percentages are
 441 significantly different among the stations (One-Way ANOVA, $p<0.001$) (Table 3).

Stations	Location	TC	TIC	TOC
St2	Proximal	2.78 \pm 0.03	2.59 \pm 0.07	0.20 \pm 0.04
St7	Proximal	2.84 \pm 0.05	2.44 \pm 0.05	0.40 \pm 0.04
St1	Medial	2.78 \pm 0.01	2.65 \pm 0.02	0.12 \pm 0.01
St3	Medial	2.75 \pm 0.03	2.26 \pm 0.08	0.48 \pm 0.05
St4	Medial	2.68 \pm 0.02	2.30 \pm 0.04	0.38 \pm 0.03
St5	Medial	3.10 \pm 0.01	2.40 \pm 0.07	0.70 \pm 0.04
St8	Distal	2.76 \pm 0.05	2.28 \pm 0.01	0.48 \pm 0.03
St6	Distal	3.04 \pm 0.03	2.39 \pm 0.02	0.65 \pm 0.02
St9	Distal	2.73 \pm 0.02	2.07 \pm 0.03	0.65 \pm 0.02

442 **Table 3.** Total carbon (TC), Total Inorganic Carbon (TIC) and Total Organic Carbon (TOC) percentages
 443 measured on the uppermost sediment layer (0-0.5 cm) at each sampling station. Data are displayed as
 444 mean \pm standard deviation (n=3).

445 4.1.4 Correlation between environmental variables

446 Few significant relationships were observed between environmental variables (Fig. S2). The
 447 most significant correlations were observed between distance from the glacier front and
 448 turbidity of surface waters ($r = -0.969$, $p < 0.001$) and between sampling depth and sediment
 449 clay percentage ($r = -0.90$, $p < 0.001$). Distance from the front was also significantly correlated
 450 with TIC and TOC percentages in sediment ($r = -0.739$, 0.729 , respectively, $p < 0.05$).

451 4.2 Foraminiferal assemblages in the upper 5 cm sediment (>150 μm fraction)

452 4.2.1 Abundances and diversity

453 Foraminiferal absolute densities and diversity metrics, considering the 0-5 cm sediment
 454 interval and the >150 fraction, are displayed in Table 4. Abundances were below 300
 455 ind. 50 cm^{-2} in the three stations closest to the glacial front (proximal stations St2 and St7 and
 456 the first medial station St1). The other medial and distal stations located beyond 6 km from the
 457 terminus showed abundances between 1700 and 3500 ind. 50 cm^{-2} (except St4 with 658
 458 ind. 50 cm^{-2}). The number of species was about or below 10 in the innermost proximal stations
 459 (St2 and St7) and almost double at the first medial station (St1), whereas all the other stations
 460 showed a species richness between 32 and 49. Low values of Shannon-Wiener Index H' were
 461 found at the proximal stations (below 1), a small increase in diversity was observed at St3, St6
 462 and St8 (values between 1 and 2), whereas higher H' values (above 2) were observed at St1,
 463 St4, St5 and St9. The equitability (J , Table 4) was below 0.50 at St2, St3, St7 and St8, whereas
 464 higher values (up to 0.73) were observed at the other locations.

Stations	Transect location	Density (ind. 50cm^{-2})	Richness (S)	Shannon-Wiener (H')	Equitability (J)
St2	Proximal	261	8	0.91	0.44
St7	Proximal	238	10	0.99	0.43
St1	Medial	263	19	2.16	0.73
St3	Medial	2308	34	1.12	0.32

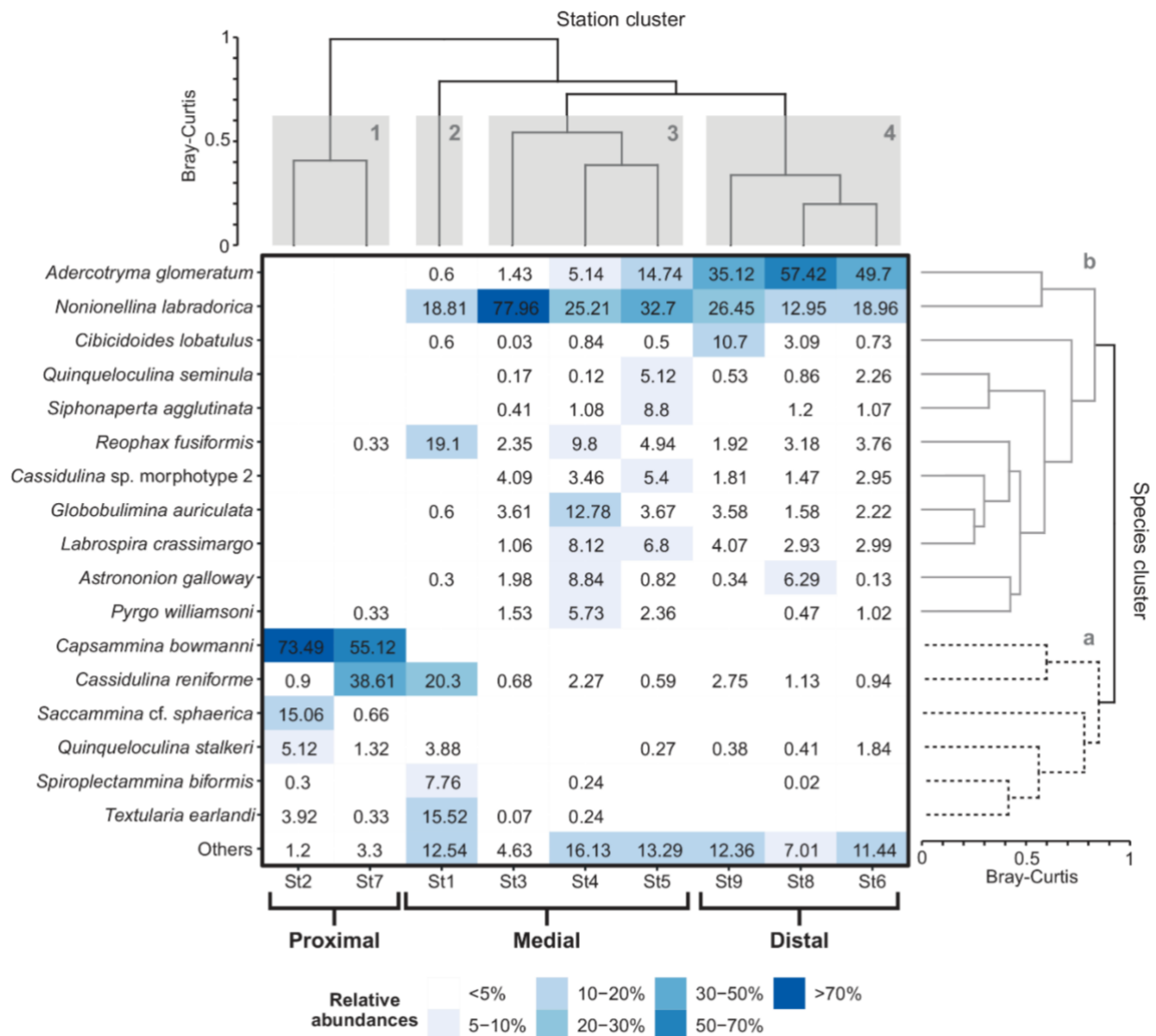
St4	Medial	658	36	2.60	0.73
St5	Medial	1733	45	2.45	0.64
St8	Distal	3485	49	1.78	0.46
St6	Distal	1841	43	1.97	0.52
St9	Distal	2086	32	2.10	0.61

465 **Table 4.** Foraminiferal total abundances (in number of individuals per 50 cm²) and diversity metrics
466 (richness, equitability and Shannon-Wiener index), considering the total living fauna (>150 µm size
467 fraction) in the 0 to 5 cm core top sediment.

468 4.2.2 Assemblage composition

469 The first cluster analysis divided the sampling stations into four clusters: cluster 1 composed
470 by the proximal stations (St2 and St7), cluster 2 including only the first medial St1, cluster 3
471 grouping the remaining medial stations (St3, St4, and St5) and cluster 4 for the distal stations
472 (St8, St6, and St9) (Fig. 3). The second cluster analysis, performed on the most abundant
473 species only, divided the species in two major groups: group *a* including species present in the
474 proximal stations and first medial station, and group *b* including species present mostly in the
475 other medial and distal stations (Fig. 3).

476 Foraminiferal species composition in terms of relative abundances is shown in Figure 3 and
477 scanning electron micrographs (SEM) of the major species are displayed in Plate 1 and 2. The
478 proximal station St2 was dominated by the agglutinated *Capsammina bowmanni* (73%) and
479 *Saccammina cf. sphaerica* (15%), with a minor contribution from the miliolid *Quinqueloculina*
480 *stalkerii*. *Capsammina bowmanni* was also dominant at the other proximal station St7 (55%),
481 together with the calcareous *Cassidulina reniforme* (39%). *Cassidulina reniforme*, *Nonionellina*
482 *labradorica*, *Reophax fusiformis* and *Textularia earlandi* were the main species at the medial
483 St1 with abundances between 15 and 20%. The medial St3 assemblage was characterised by
484 *Nonionellina labradorica* (78%), which was also a major component in the medial and distal
485 stations (with abundances between 13 and 33 %). *Globobulimina auriculata* made up to 13%
486 at St4. The agglutinated *Adercotryma glomeratum* showed high relative abundances (between
487 35 and 57%) at the distal stations (St8, St6, St9). *Cibicidoides lobatulus* reached the 11% only
488 in the outermost station St9.



490

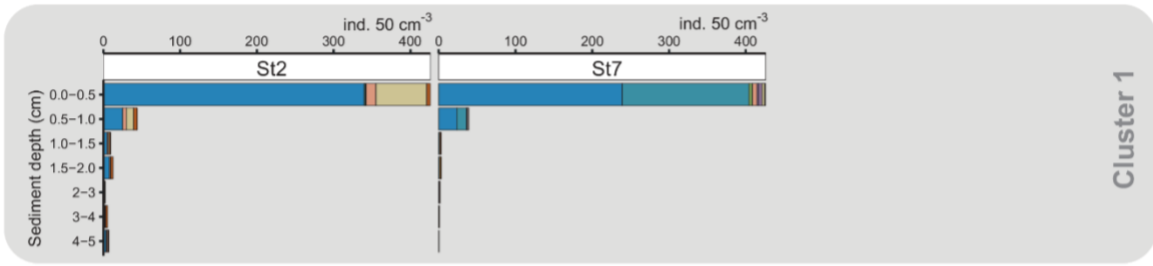
491 **Figure 3.** Heatmap showing the cluster analysis of the foraminiferal fauna based on relative abundances
 492 of the major species considering the total living faunas (>150µm size fraction) in the 0 to 5 cm core top
 493 sediment. The dichotomy clustering is based on the Bray-Curtis dissimilarity. The station cluster
 494 (complete linkage method) considers all the species whereas the species cluster (average linkage
 495 method) considers only the relative abundances of the major species (>5 %).

496 **4.2.3 Microhabitat distribution**

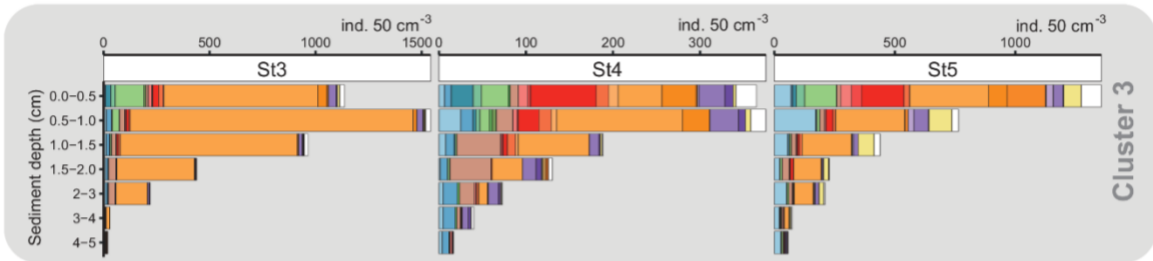
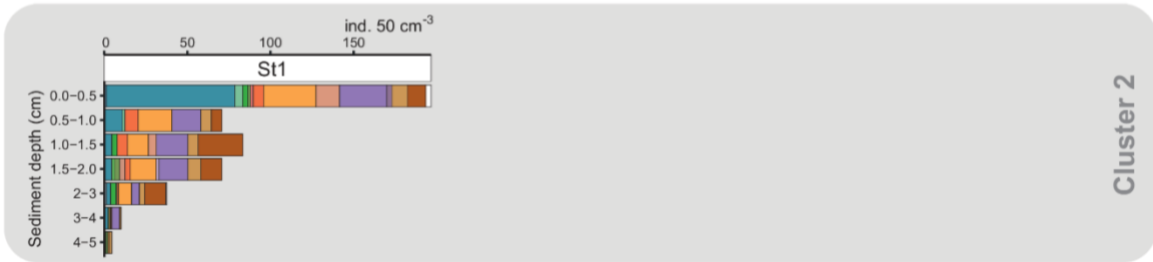
497 The foraminiferal vertical distribution profiles from the surface down to 5 cm sediment depth
 498 were heterogeneous along the fjord axis (Fig. 4). Living foraminifera were present mostly in
 499 the uppermost half centimetre of sediment, rapidly disappearing downcore at the two proximal
 500 stations (St2 and St7; cluster 1). This surface layer was dominated by *C. bowmanni* and

501 *Saccamina* cf *sphaerica* at St2, whereas St7 was characterised by *C. bowmanni* and *C.*
502 *reniforme*. Cluster 2 including only St1 shows the presence of *C. reniforme* mostly in the 0-0.5
503 cm layer together with other species (e.g., *N. labradorica*, *R. fusiformis* and *T. earlandi*). The
504 three medial stations of cluster 3 (St3, St4, St5) showed the typical exponential decrease in
505 foraminiferal density with sediment depth. Some species were mostly present in the uppermost
506 centimetre (e.g., *Cassidulina* sp. morphotype 2 and *Labrospira crassimargo*). The only species
507 abundant below the 0-0.5 cm layer were *N. labradorica*, particularly at St3, and *Globobulimina*
508 *auriculata*, even more abundant at the 1-2 cm layer of St4. In the distal stations (cluster 4),
509 deep infauna (i.e., *A. glomeratum* and/or *N. labradorica*) was encountered. Foraminiferal
510 densities at St6 remained similar at all layers below the 0.5 cm depth. On the contrary St9
511 showed a subsurface peak at 1-2 cm depth with foraminiferal density almost double than the
512 uppermost centimetre due to the high density of *A. glomeratum* and *N. labradorica*. The
513 intermediate and deep infaunal microhabitats showed similar species compositions than the
514 uppermost centimetre.

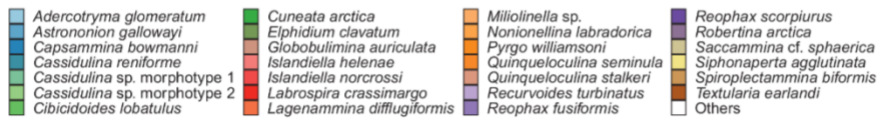
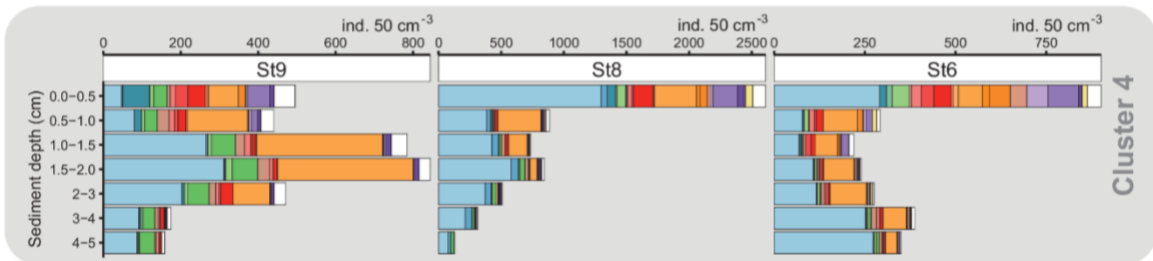
Proximal stations



Medial stations



Distal stations

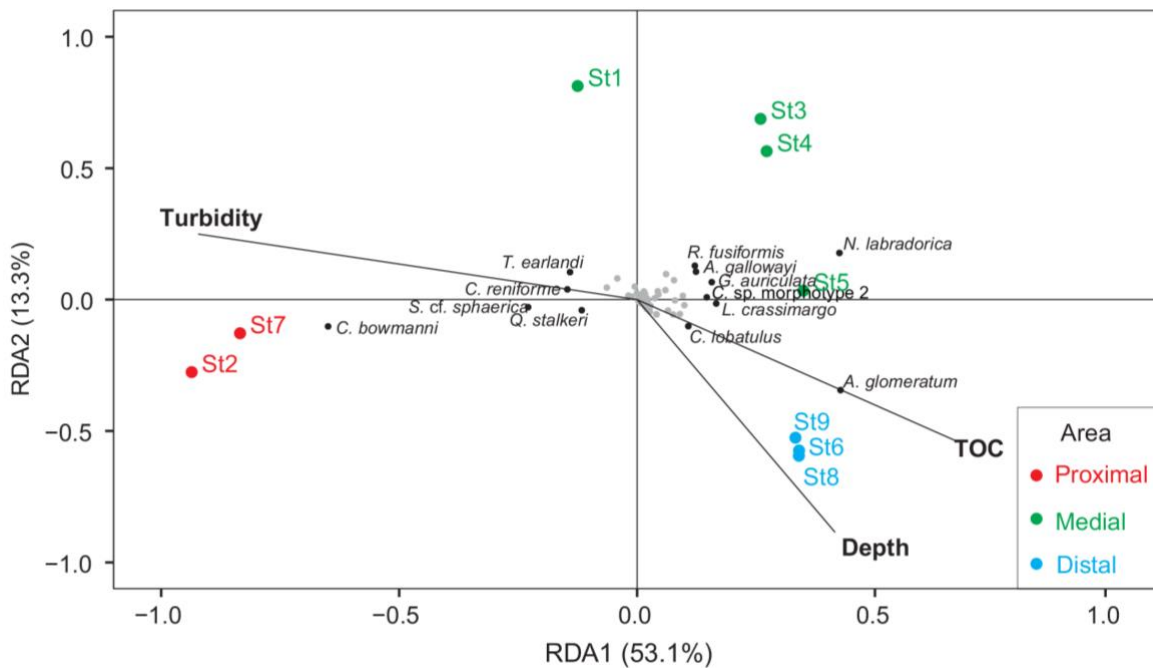


515

516 **Figure 4.** Foraminiferal microhabitat distribution of the most representative species (contributing with
 517 >5% in at least one sample) from the sediment surface down to 5 cm depth considering the >150 µm
 518 fraction. Note that stations are displayed based on their location (proximal, medial, distal) and on the
 519 results of the station cluster analysis displayed in Fig. 3.

520 4.2.3 Redundancy analysis

521 Three predictors of variation in species composition were identified from the redundancy
 522 analysis (turbidity and depth $p < 0.05$; TOC, $p < 0.1$). The first two components of the model
 523 explained 66.4% of the total variance (r^2 adjusted = 0.59). RDA1 was positively correlated with
 524 sediment organic matter content (TOC) and water depth, and negatively with surface water
 525 turbidity. Opposite correlations were observed for the RDA2. RDA1 separates the proximal
 526 stations plus St1 from the other medial and distal stations. RDA2 separates proximal and distal
 527 stations from the medial stations. The proximal stations were positively correlated with
 528 turbidity, whereas the distal stations with TOC and depth. The three species with the highest
 529 scores are *C. bowmanni*, *N. labradorica* and *A. glomeratum*, which were the major species
 530 respectively at the proximal, medial and distal stations.



531
 532 **Figure 5.** Transformed-based redundancy analysis (tb-RDA) performed on living foraminiferal
 533 community (total densities in the 0-5 cm interval, >150 μ m fraction) in relation to three significant
 534 environmental parameters (surface water turbidity in the 0-20 m surface layer, percentage of TOC, and
 535 sampling water depth).

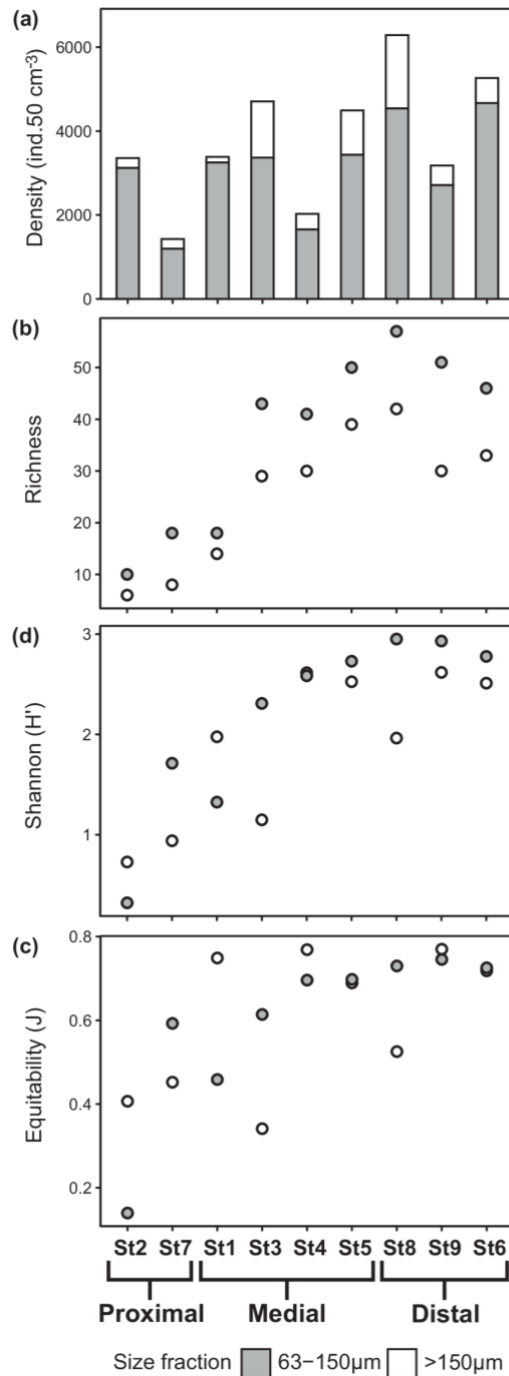
536 **4.3 Comparison between the 63-150 μm and > 150 μm size fractions (in the 1 cm core**
537 **top)**

538 *4.3.1 Abundance and diversity*

539 Foraminiferal densities and diversity metrics were calculated considering the 63-150 μm and
540 >150 μm fractions in the 0-1 cm sediment layer (Fig. 6). The finer fraction (63-150 μm) showed
541 abundances always higher than the coarse fraction (>150 μm) with densities between 1000
542 and 4700 ind. 50 cm^{-2} . The small fraction contributed from 72 up to 96% to the total densities
543 (63-150 μm + >150 μm) (Fig. 6a). Foraminiferal densities considering the >150 μm were lower
544 than 300 ind. 50 cm^{-2} at St2, St7 and St1, between 300 and 600 ind.50 cm^{-2} at St4, St6 and St9
545 and over 1000 ind.50 cm^{-2} at St3, St5 and St8.

546 Less than 20 species were observed for both size fractions in the first three stations of the
547 transect (St2, St7 and St1), whereas values between 29 and 57 were observed further away
548 in the transect. The number of species observed in the finer fraction was always higher than
549 in the coarse fraction but with a similar trend along the main fjord axis (Fig.6b).

550 Shannon-Wiener index was lower than 2 at the three innermost stations, whereas values
551 between 2 and 3 were observed further away in the transect considering the finer fraction (63-
552 150 μm). The >150 fraction presented values lower than 1.5 at the station St2, St7 and St3,
553 values around 2 at St1 and St8, while the remaining stations showed values around 2.5.
554 Equitability values for the >150 μm fraction were below 0.5 at St2, St7 and St3, whereas values
555 between 0.5 and 0.8 were observed at all other stations. The finer fraction (63-150 μm) showed
556 very low equitability at St2, values between 0.5 and 0.6 at St7, St1, and St3, and over 0.7 at
557 the other stations. Shannon-Wiener and equitability diversity metrics showed more variability
558 between the two size assemblages (Fig. 6c, d) compared to species richness (Fig. 6a), but a
559 similar diversity increase from the inner to the outer stations was observed.



560

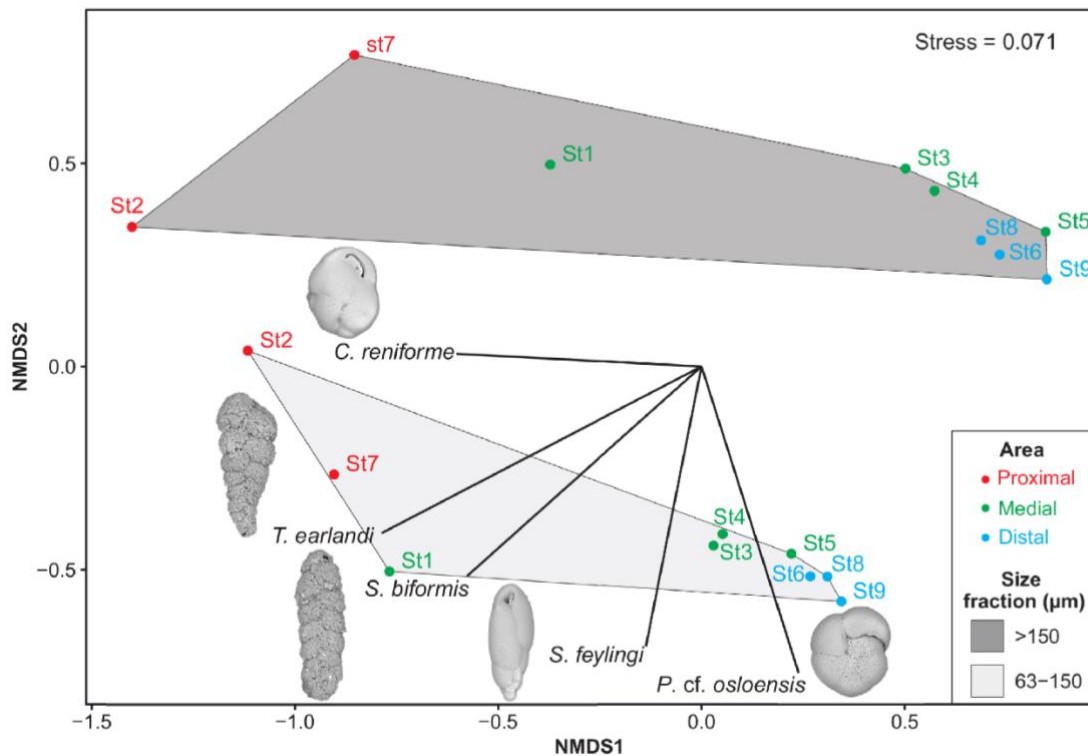
561 **Figure 6. (a)** Foraminiferal cumulative densities (ind. 50 cm⁻³) for two size fractions (63-150 μm > 150
 562 μm) of the 0-1 cm sediment layer. **(b)** Shannon-Wiener (H') and **(c)** equitability (J) indexes comparison
 563 among the 63–150 μm and >150μm fractions. The >150 μm fraction is represented in dark grey and the
 564 63-150 μm in light grey.

565 *4.3.2 Non-metric multidimensional scaling analysis*

566 The nMDS ordination plot (stress = 0.071), based on species densities considering the fine
 567 (63-150 μm) and coarse (>150 μm) size fractions in the 0-1 cm sediment layer, showed a

568 similar clustering of the stations by area (proximal, medial, distal) but differences in
 569 assemblage composition (Fig. 7). The NMDS1 axis separates the first three stations of the
 570 transect (St2, St7, and St1) from the remaining stations, whereas NMDS2 separates the two
 571 size fractions. The area of the polygon for the >150 µm size fraction is bigger than the one for
 572 the 63-150 µm, indicating lower dissimilarity among stations in the finer fraction.

573 Although both fractions separated the nine stations into the same stations' clusters,
 574 overlap can be observed between convex hulls due to large differences in foraminiferal
 575 assemblages (Fig. 7). Indeed, the SIMPER analysis identified five major species (i.e.,
 576 *Cassodulina reniforme*, *Textularia earlandi*, *Spiroplectammia biformis*, *Stainforthia feylingi*,
 577 *Pullenia cf. osloensis*) influencing this difference (average contribution >5%, $p < 0.01$). Four of
 578 them were positively correlated with the NMDS2 axis and mostly represented in the 63-150
 579 µm fraction. The only exception being *C. reniforme*, which was almost equally present in both
 580 fractions. The two size fractions had 50 common species. The >150 µm had 14 exclusive
 581 species, whereas the 63-150 µm presented 21 exclusive species. Species relative abundances
 582 for both size fractions are displayed as heatmaps in the supplement (Fig. S3).



583

584 **Figure 7.** Non-metric multidimensional scaling (nMDS) analysis (Bray-Curtis dissimilarity) on
585 foraminiferal densities considering two groups corresponding to the two size fractions (63-150 μm and
586 $>150 \mu\text{m}$) in the 0-1 cm. Station colours correspond to the sampling area (proximal, medial, distal). The
587 convex hulls enclosed each of the groups. The displayed vectors are the species explaining significant
588 ($p < 0.01$) percentage of dissimilarity ($>5\%$) between the two groups based on SIMPER analysis.

589 **5. Discussion**

590 The geographical position of Kongsfjorden and its geometric configuration (i.e., no entrance
591 sill) are responsible for the built-up of steep environmental gradients developing along the short
592 fjord axis between two contrasted end-members (Lalande et al., 2016; Meslard et al., 2018;
593 Svendsen et al., 2002). Gradients of water salinity and temperature, turbidity, nutrient
594 distribution, and inorganic particulate sedimentation, are determined by the concomitance of
595 glacier dynamics at the fjord head with the AW inflow from the outer shelf. The present study,
596 performed in August 2018, shows that benthic foraminiferal faunas respond clearly to these
597 summer environmental gradients. Our analyses identified three biozones related to the glacier
598 front in the inner Kongsfjorden: distal, medial and proximal.

599 *1. Proximal biozone*

600 During August 2018, CTD casts detected a water column typical of the summer stratification
601 (Svendsen et al, 2002; Cottier et al. 2005) with a fresh surface layer of meltwaters overlying
602 saltier water mass (due to mixing with AW) (Fig. 1). The surface layer also revealed high
603 turbidity, particularly in the vicinity of the front of the tidewater glacier Kronebreen (Fig. S2).
604 This observation confirms previous studies that identified the Kronebreen glacier as the major
605 source of meltwater, suspended particles and sediment in the Kongsfjorden (D'Angelo et al.,
606 2018; Meslard et al., 2018; Svendsen et al., 2002; Trusel et al., 2010). Generally, Kronebreen
607 subglacial discharges and associated sediment load eroded from the glacier basement exit
608 from the northernmost part of the glacier front (Meslard et al., 2018; Trusel et al., 2010).
609 Consequently, a buoyant turbid plume is formed at the tidewater glacier front and is pushed
610 away northwards by the downfjord surface circulation at the fjord head (Sundfjord et al., 2017;

611 Torsvik et al., 2019), implying the spreading of the plume above our sampling stations St2 and
612 St7 (Fig. 1). The fine grained particles, transported in suspension in the plume are deposited
613 with a high sediment rate estimated at about 6-9 cm y⁻¹ in the vicinity of the Kronebreen front
614 (< 0.5 km) (Trusel et al., 2010). This explains our observations at the proximal stations where
615 unconsolidated and potentially high mobile surface sediment (i.e., low sediment stability) was
616 composed of medium silt. Coarser particles from subglacial discharges, such as coarse silt
617 and fine sand, can also be transported in suspension in the plume during sporadic
618 hydrodynamic events (e.g., accelerated melting period, surge, storm), and then deposited
619 along a decreasing size gradient off the glacier front (Torsvik et al., 2019). This process may
620 be recorded by layers of coarse silts like observed 3 cm downcore at St2.

621 The proximal stations (St2 and St7), grouped into cluster 1 (Fig. 3), were positively
622 correlated with surface water turbidity (Fig. 5). This area, directly subjected to high
623 sedimentation from the meltwater turbid plume was characterised by low foraminiferal
624 abundances and/or low taxonomic diversity in both size fractions (Table 3, Fig. 6). Only few
625 species (i.e., *Capsammina bowmanni*, *Saccammina cf. sphaerica*, *Cassidulina reniforme* and
626 *Textularia earlandi*) that are most likely adapted to colonise soft-bottom sediments subjected
627 to high physical disturbance, were identified in this area (Fig. 3 and Fig. 7). The agglutinated
628 monothalamus species *C. bowmanni* completely dominated the assemblage in the immediate
629 proximity of the glacier (St2, 1.9 km far from the glacier front). This species lives preferentially
630 in the uppermost centimetre of the sediment (Gooday et al., 2010) and was previously reported
631 in a temperate fjord under fluvial influence in southern Norway (e.g., Alve and Nagy, 1986).
632 However, it has never been reported as a dominant species and its presence has not been
633 often documented, likely due to the fragility of the test that can be lost during sample
634 preparation. At St7, *C. bowmanni* was accompanied by *C. reniforme* and *T. earlandi*. The
635 increased distance (about 4.5 km) from the glacier front and a consequent slightly reduced
636 environmental stress may have favoured the coexistence of these species. *Cassidulina*
637 *reniforme* is a typical glacier proximal species that has been previously observed in several
638 Svalbard fjords from the western coast (Adventfjorden, Hornsund, Van Mijenfjorden, Isfjorden,

639 Tempelfjorden, Krossfjorden, Smeerenburgfjorden; Hald and Korsun, 1997; Korsun and Hald,
640 2000; Szymańska et al., 2017) and from the southern coast (Storfjorden; Fossile et al., 2020).
641 This species was suggested to prefer less saline waters (e.g., Hald and Korsun, 1997; Jernas
642 et al., 2018). *Cassidulina reniforme* was also present as juveniles in the fine fraction at the
643 proximal station St7. The presence of juveniles of this glacier-proximal species (e.g., Hald and
644 Korsun, 1997; Korsun and Hald, 1998, 2000) may suggest the opportunistic response to the
645 stressful conditions related to glacier dynamics (i.e., high turbidity and reduced organic flux).
646 In other Svalbard fjords, *C. reniforme* is often accompanied by another glacier proximal
647 opportunist, *Elphidium clavatum* (e.g., Hald and Korsun, 1997; Korsun and Hald, 1998, 2000;
648 Fossile et al., 2020). In the studies mentioned above, it was proposed that *C. reniforme* would
649 replace *E. clavatum* when environmental conditions ameliorate in terms of glacial physical
650 disturbance and food supply. In our study *E. clavatum* was observed only in the dead
651 assemblages, suggesting a potential temporal shift in the dynamics for their reproduction
652 (Table S2). Indeed, high frequencies of *E. clavatum* and *C. reniforme* were documented in
653 September 2015 at the Kongsfjorden head (Kniazeva and Korsun, 2019). In the small size
654 assemblage of St7 there was also the agglutinated *T. earlandi*. This is a typical glaciomarine
655 species usually found in fjord environments (e.g., Korsun and Hald, 2000).

656 The meltwater turbidity plume can spread for several kilometres from the glacier front
657 (Meslard et al., 2018) reducing the euphotic depth to few meters (Halbach et al., 2019) and
658 locally preventing phytoplankton growth. Moreover, glacial runoff transports old and refractory
659 terrestrial organic carbon (Bourgeois et al., 2016; Calleja et al., 2017; Kedra et al., 2012). This
660 generally causes the depletion of available organic matter export fluxes to the seafloor in the
661 inner fjord (Lalande et al., 2016). Previous studies reported sediment depleted in organic
662 carbon close to the Kronebreen terminus (TOC% < 0.25%; Bourgeois et al., 2016).

663 The presence of living foraminifera restricted at the sediment surface (Fig. 4) was likely due
664 to the unconsolidated and potentially mobile sediment (i.e., low sediment stability) caused by
665 rapid accumulation from high suspended sediment load coming from the glacier terminus. But,
666 it can also be a response to the poor TOC concentrations lower or about 0.4% (TROX model,

667 Jorissen et al., 1995). Deposition of massive amounts of sediments can also hamper the
668 oxygen penetration into the sediment. It is well known that oxygen availability as well as organic
669 matter are two limiting factors for foraminiferal microhabitat distribution (Jorissen et al., 1995).
670 Moreover, the presence of *C. bowmanni* and *C. reniforme* restricted at the sediment surface
671 may be the result of their microhabitat preferences. High absolutes and relative densities and
672 microhabitat restriction might be indicative of the pioneer character of *C. bowmanni*. The
673 presence of opportunistic and simple agglutinated species capable of rapid colonisation after
674 physical disturbance was previously observed in highly disturbed areas (i.e., canyons; Koho
675 et al., 2007). This species, together with *T. earlandi* and the calcareous *C. reniforme*, may be
676 the only species able to deal with the stressful conditions prevailing at the sampling time.
677 Similar habitat restrictions to the sediment-water interface were observed for benthic
678 macrofauna in some areas of Arctic fjords subjected to high disturbance (e.g., Wlodarska-
679 Kowalczyk et al., 2005). Finally, the high availability of mica at the Kronebreen terminus
680 originated from mica-schists (from Proterozoic low- and medium-grade metamorphic rocks;
681 Svendsen et al., 2002), could have also played a positive role in the thriving of *C. bowmanni*.
682 Indeed, this species appears to have an obligated use of mica flakes to build its test (Gooday
683 et al., 2010).

684 *II. Medial biozone*

685 In the central part of the inner fjord, the water column was characterised by the same fresh
686 surface layer and a clear signal of AW intrusion (Fig. 1). A reduced water turbidity compared
687 to the proximal area was observed (Fig. S1). The increased distance from the glacier front and
688 a progressive dispersal of the meltwater turbid plume coming from Kronebreen can explain
689 such pattern (e.g., Meslard et al., 2019). Medium silts were also observed in this area, as a
690 result of the sedimentation from the meltwater turbid plume away from the glacier front. Indeed,
691 high sedimentation rates were previously estimated to values of about 2.5 cm yr⁻¹ in the medial
692 zone, but they are 2.5 to 3.5 times lower than the ones measured in the proximal zone
693 (Zaborska et al., 2006). At the two shallowest stations St3 and St4, located in front of glacial

694 sandur deltas, in the vicinity of prodeltas (Bourriquen et al., 2016) developed along the
695 southern coast, coarse silts were observed as a secondary peak in the grainsize distribution
696 of down core sediment layers. This relatively coarse particulate input to the fjord may be
697 provided by meltwaters (and associated sedimentary load) derived from the sandur drainage
698 downstream the continental glaciers (i.e., Austre Lovénbreen and Midtre Lovénbreen) located
699 on the southern bank of the fjord (Bourriquen et al., 2018).

700 The medial stations grouped into cluster 2 (St1 alone) and cluster 3 (St3, St4 and St5) (Fig.
701 3) do not show any strong correlation with a specific environmental variable (Fig. 5), but
702 foraminiferal communities showed some differences between the two identified clusters. St1
703 was separated from the remaining medial stations and it was composed by a transitional
704 assemblage from the proximal to the medial biozone, characterised by the presence of *C.*
705 *reniforme*, *Reophax fusiformis* and *T. earlandi*. *Cassidulina reniforme*, which was also
706 dominant in the proximal station assemblages, could indicate the persistence of the tidewater
707 glacier disturbance, as also suggested by the presence of juveniles of this species. Moreover,
708 the relatively high disturbance at St1 is supported by the lowest TOC content (around 0.1 %)
709 measured along the transect. *Textularia earlandi*, was the dominant species in the small size
710 assemblage of St1. This elongated species together with *Spiroplectammia biformis* was
711 mostly present in the fine fraction and especially in the medial stations (Fig. 7, Fig. S3). Both
712 species are typical of glaciomarine environments, and their relative abundances usually
713 increase with distance from the glacier but still under glacier influence (e.g., Korsun and Hald,
714 2000; Forwick et al., 2010; Szymańska et al., 2017; Fossile et al., 2020). The agglutinated *R.*
715 *fusiformis* was previously observed together with *T. earlandi*, in a West Greenland fjord, an
716 Arctic fjord under the influence of Atlantic-sourced waters (Lloyd, 2006). The preference of
717 both species for these waters is coherent with their presence in August 2018 when an AW
718 intrusion was clearly observed in the medial area. Station St1 presented also high relative
719 abundances of *Nonionellina labradorica*, which is in common with all the other medial stations
720 grouped into cluster 3, underlying the transitional character of this station.

721 At all the stations grouped into cluster 3, the calcareous species *Nonionellina labradorica*
722 was the major species with variable relative abundances. This is a typical glacier-distal
723 species, of which the distribution was often related to nutrient enrichment or to the presence
724 of AW (Hald and Korsun, 1997; Korsun and Hald, 1998). This species preferentially feeds on
725 diatoms (e.g., Cedhagen, 1991; Jernas et al., 2018) and its location at the sediment surface
726 may indicate the presence of fresh phytodetritus inputs, which is mostly composed of diatoms
727 in the inner Kongsfjorden (Lalande et al., 2016). The presence of *N. labradorica* is compatible
728 with the slightly higher organic carbon content measured in the stations of cluster 3 (0.4-0.7 %
729 of TOC) (Table 3). Indeed, the fjord dynamics, with the deep AW intrusion, consequent
730 subglacial-induced upwelling at the glacier terminus and downfjord surface advection, can
731 supply nutrients (i.e., nitrate and phosphate) in this medial area enhancing primary productivity
732 (Halbach et al., 2019). Several other minor species (e.g. *Quinqueloculina seminula*, *Labrospira*
733 *crassimargo*, *Astrononion gallowayi*, *Siphonaperta agglutinata* and *Adercotryma glomeratum*)
734 often found in Svalbard fjords (e.g., Hald and Korsun, 1997; Korsun and Hald, 2000; Forwick
735 et al., 2010; Jernas et al., 2018; Kniazeva and Korsun, 2019) were identified in the medial
736 stations and are the reason for the increased diversity measured in this area compared to the
737 innermost part of the fjord (Table 3). The fine fraction at these stations was characterised by
738 the elongated calcareous species *Stainforthia feylingi*. This species was previously found in
739 the outer Kongsfjorden (Jernas et al, 2018), but little is known about its ecology. This species
740 is reported as opportunist (e.g., Lloyd et al., 2007) and often associated to high primary
741 productivity in the vicinity of sea ice in paleoenvironmental reconstructions (e.g., Seidenkrantz,
742 2013). In August 2018, *S. feylingi* co-occurred with a phytodetritus indicator (i.e., *N.*
743 *labradorica*), which supports the speculation of its preferences for that food resource. The
744 small fraction at station St5 was dominated by the small-sized species *Pullenia cf. osloensis*
745 which presented high relative abundances also in the distal stations.

746 The microhabitat distribution in the >150 µm fraction showed decreased foraminiferal
747 abundances with sediment depth. The downcore microhabitat distribution of *N. labradorica*
748 showed subsurface peaks that demonstrate its capacity to occupy infaunal habitats. This

749 suggests a potential ability to exploit other food resources than fresh phytodetritus (e.g., buried
750 organic matter; Corliss, 1991; Alve, 2010) or to benefit from an alternative metabolism (e.g.
751 denitrification, Jauffrais et al., 2019). Indeed, some closely related species are capable of
752 denitrification (e.g., *Nonionella* sp. T1 and *Nonionella cf stella*; Glock et al., 2019; Choquel et
753 al., 2021) and thus can successfully occupy and exploit subsurface sediment resources.
754 *Globobulimina auriculata* also displayed a subsurface increase at St4. This behaviour can be
755 explained by its tolerance for low oxygen conditions and/or denitrification capacity as other
756 *Globobulimina* species (e.g., Risgaard-Petersen et al., 2006; Koho et al., 2011) and thus able
757 to occupy infaunal habitats where interspecific competition is reduced. The microhabitat
758 distribution observed in the medial stations may also result from reduced sediment deposition,
759 increased sediment stability, increase in organic flux, and therefore the development of diverse
760 suitable ecological niches to occupy.

761 III. *Distal biozone*

762 The outer part of the transect was characterised by a fresh surface layer and by an
763 intermediate water and deep layer of AW (Fig. 1). This part of the fjord, deeper than 100 m, is
764 directly influenced by the inflow of warm and salty AW coming from the WSC current flowing
765 along the western coast of Svalbard. The lowest values of surface turbidity were observed in
766 this area of the fjord (Fig. S1). The increased water transparency was the result of augmented
767 distance from the Kronebreen front. However, we observed the same type of sediment (i.e.
768 medium silt) than upstream. This could suggest that this area is still impacted by the
769 sedimentation from a diluted turbid plume. At St8, which is located close to the southern coast,
770 the coarser medium silt of the fjord sediment was observed with a secondary mode of very fine
771 sand. This may suggest sediment inputs from continental glacier meltwaters (i.e., Midtre
772 Lovénbreen). Unfortunately, the local sedimentation rate is unknown.

773 The distal stations grouped into cluster 4 (St6, St8 and St9) (Fig. 3) were positively
774 correlated with sediment organic carbon and water depth (Fig. 5). The dominant species was
775 the agglutinated *Adercotryma glomeratum* followed by the calcareous *N. labradorica* (Fig. 3).

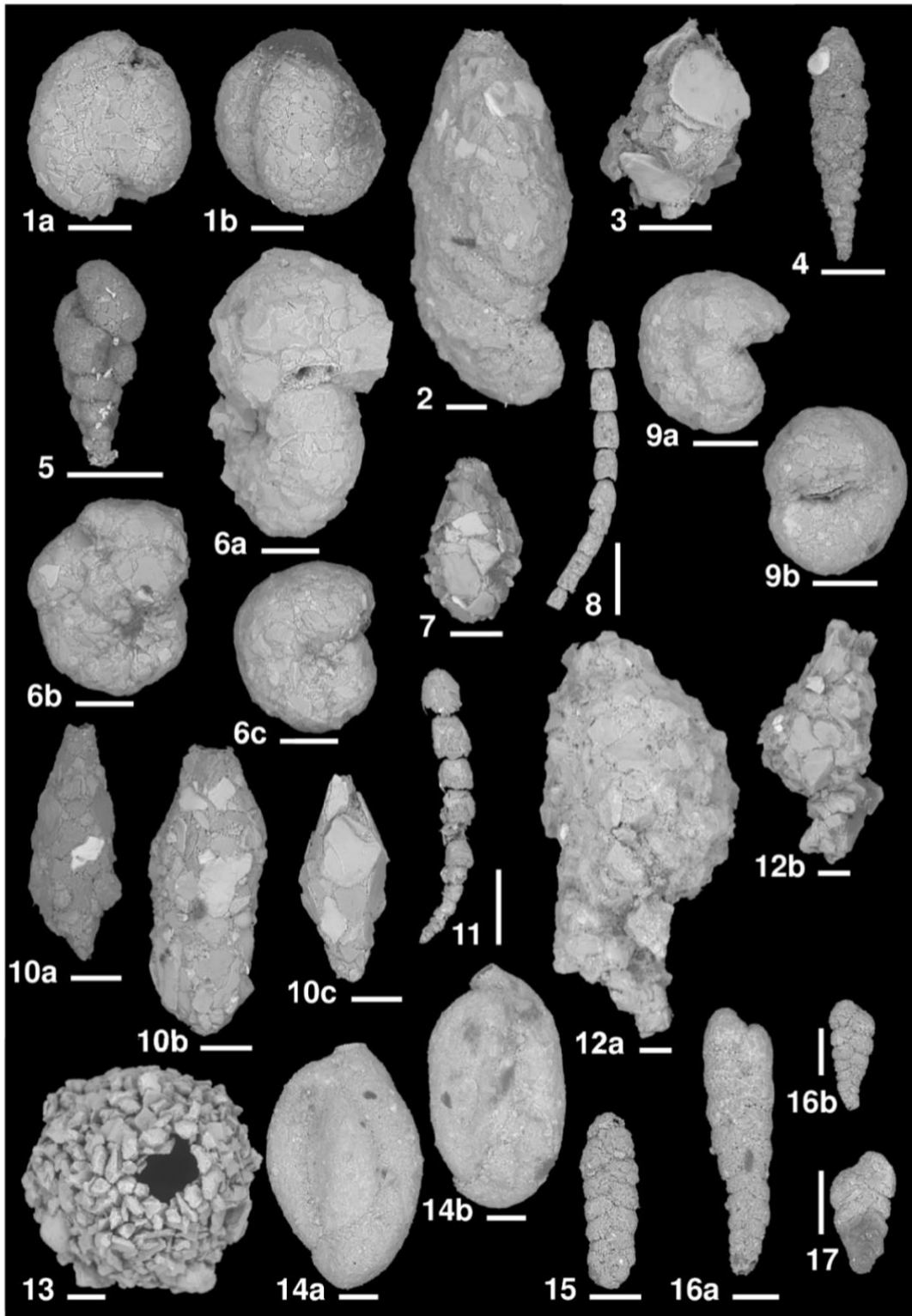
776 *Adercotryma glomeratum* was suggested to be able to exploit low food quality and/or quantity
777 (Jernas et al., 2018), whereas *N. labradorica* is supposed to feed on fresh phytodetritus or to
778 have different metabolism (i.e., able of denitrification; see references above). The coexistence
779 of these two species may be explained by the occupation of different ecological niches.
780 *Adercotryma glomeratum* was also previously related to AW influence in the Kongsfjorden
781 (Jernas et al., 2018), in other western Svalbard fjords including Isfjorden and Krossfjorden
782 (Korsun and Hald, 1997), and in the southern fjord Storfjorden (Fossile et al., 2020). The clear
783 dominance of this species in the distal stations and its decreasing percentage in the medial
784 area (where represented only a minor proportion of the assemblages), suggests the decline in
785 the AW influence upstream fjord. This is coherent with AW intrusion invading the fjord trench
786 from the outer sea and perhaps suggests a longer persistence of AW at the distal stations. At
787 St 9, *Cibicidoides lobatulus* is highly present and could indicate high-energy near-bed currents
788 at this station (Murray, 2006).

789 The fine fraction (63-150 μm) of the distal stations and were characterised by the presence
790 of the small-sized species *Pullenia cf. osloensis*. The ecological preferences of *P. cf. osloensis*
791 have not been previously described. *Pullenia* spp. were previously reported as detritivore and
792 typically found on the shelf-bathyal area of cold environments (Murray, 2006). Some species
793 of this genus are often used as AW indicators in paleoenvironmental studies (e.g., Chauhan
794 et al., 2016 and reference therein), potentially explaining the presence of this species mostly
795 at St5 and in the distal stations that are under the inflow of AW (Fig. S3). Moreover, *Stainforthia*
796 *feylingi* showed important relative abundances at the outermost station St9 suggesting
797 increased phytodetritus inputs at this location (e.g., Lloyd et al., 2007; Seidenkrantz, 2013).

798 Even if foraminiferal species composition was similar among the distal stations, the
799 microhabitat distribution displayed some differences (Fig. 5). The subsurface peaks observed
800 at St9 (Fig. 5) was determined by the high densities of *A. glomeratum* and *N. labradorica*. Both
801 species may have preferred the infaunal habitat to exploit additional food resources (i.e., buried
802 organic matter of lower quality) or use different metabolisms (i.e., denitrification) and thus
803 reduce competition with the many species present at the sediment surface. However, *A.*

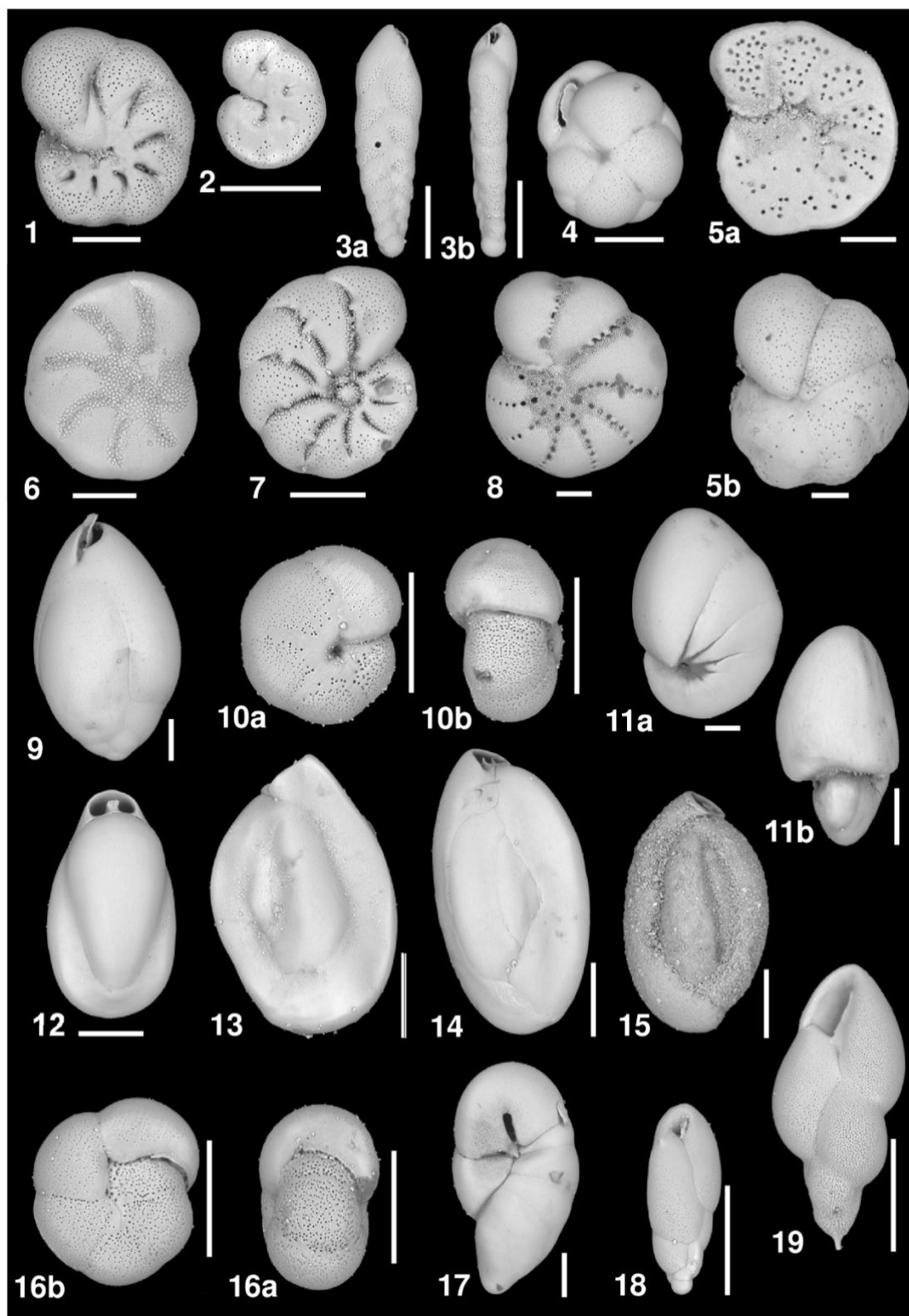
804 *glomeratum* was also present with high numbers at the sediment surface and presented a
805 deep increase in densities at St6, that may point out to bioturbation processes at these stations
806 (e.g., Thibault De Chanvalon et al., 2015).

807



808

809 **Plate 1.** Scanning electron micrographs (SEM) of the most relevant agglutinated benthic species from
810 Kongsfjorden (scale bars = 100 µm). **1a,1b.** *Adercotryma glomeratum* (Brady, 1878). **2.** *Ammotium*
811 *cassis* (Parker, 1870). **3.** *Capsammina bowmanni* (Heron-Allen & Earland, 1912). **4.** *Cuneata arctica*
812 (Brady, 1881). **5.** *Eggerella advena* (Cushman, 1922). **6a, 6b, 6c.** *Labrospira crassimargo* (Norman,
813 1892). **7.** *Lagenammia difflugiformis* (Brady, 1879). **8.** *Leptohalysis scottii* (Chaster, 1892). **9a, 9b.**
814 *Recurvoides turbinatus* (Brady, 1881). **10a, 10b, 10c.** *Reophax fusiformis* (Williamson, 1858). **11.**
815 *Reophax catella* Höglund, 1947. **12a, 12b.** *Reophax scoriurus* Montfort, 1808. **13.** *Saccammina* cf.
816 *sphaerica* Brady, 1871. **14a, 14b.** *Siphonaperta agglutinata* (Cushman, 1917). **15.** *Spiroplectammina*
817 *biformis* (Parker & Jones, 1865). **16a, 16b.** *Textularia earlandi* Parker, 1952. **17.** *Textularia torquata*
818 Parker, 1952.



819

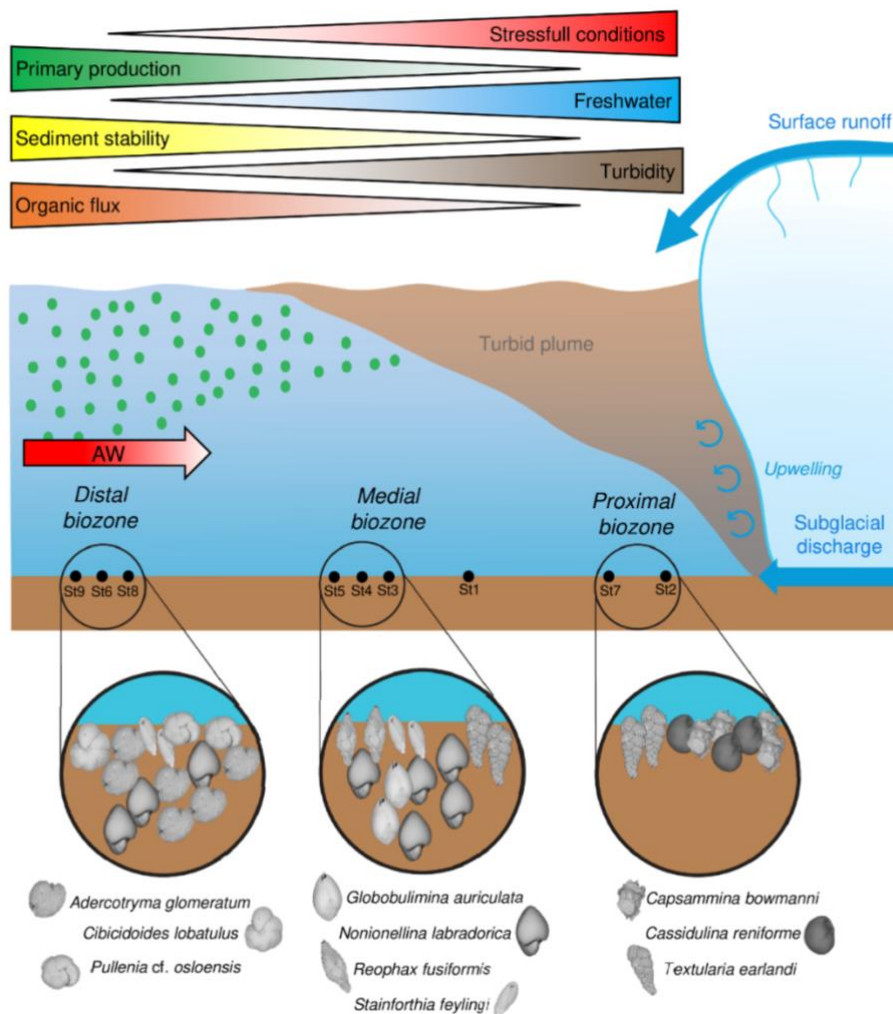
820 **Plate 2.** Scanning electron micrographs (SEM) of the most relevant calcareous benthic species from
 821 Kongsfjorden (scale bars = 100 μm). **1a,1b.** *Astrononion gallowayi* Loeblich & Tappan, 1953. **2.**
 822 *Astrononion* sp. Cushman & Edwards, 1937. **3.** *Bolivina pseudopunctata* Höglund, 1947. **4.** *Cassidulina*
 823 *reniforme* Nørvang, 1945. **5a, 5b.** *Cibicidoides lobatulus* (Walker & Jacob, 1798). **6.** *Criboelphidium*
 824 *subarcticum* (Cushman, 1944). **7.** *Elphidium clavatum* Cushman, 1930. **8.** *Elphidium bartletti* Cushman,

825 1933. **9.** *Globobulimina auriculata* (Bailey, 1894). **10a, 10b.** *Melonis pompilioides* (Fichtel & Moll, 1798).
826 **11a, 11b.** *Nonionellina labradorica* (Dawson, 1860). **12.** *Pyrgo williamsoni* (Silvestri, 1923). **13.**
827 *Quinqueloculina arctica* Cushman, 1933. **14.** *Quinqueloculina seminula* (Linnaeus, 1758). **15.**
828 *Quinqueloculina stalkerii* Loeblich & Tappan, 1953. **16a, 16b.** *Pullenia* cf. *osloensis* Feyling-Hanssen,
829 1954. **17.** *Robertina arctica* d'Orbigny, 1846. **18.** *Stainforthia feylingi* Knudsen & Seidenkrantz, 1994.
830 **19.** *Stainforthia loeblichii* (Feyling-Hanssen, 1954).

831 **6. Conclusions**

832 Living benthic foraminiferal faunas from the inner Kongsfjorden were studied to determine
833 the combined influence of glacier melting with AW inflow on the benthic system. To that aim,
834 foraminiferal patterns were investigated in relation to water masses properties, sediment
835 characteristics and organic matter inputs to the seafloor during late summer, when
836 environmental gradients are the steepest. Benthic environmental conditions were connected
837 to tidewater glacier dynamics and interpreted based on the glacial-related disturbances. The
838 surface water turbidity, water depth and the organic inputs to the seafloor are the main driving
839 factors for foraminiferal patterns in the inner Kongsfjorden, determining the establishment of
840 three different biozones (i.e., proximal, medial and distal) summarised in the conceptual model
841 (Fig. 8). High surface water turbidity related to freshwater and sediment inputs from subglacial
842 discharges and surface runoff, and reduced organic flux due to reduced primary production,
843 were the limiting factors for the proximal biozone. This inner area was dominated by few stress-
844 tolerant and/or opportunistic glacier proximal species restricted to the sediment surface (e.g.,
845 *Capsammina bowmanni*, *Cassidulina reniforme* and *Textularia earlandi*). A progressive
846 reduction of the general stressful environmental conditions (i.e., reduced physical disturbance
847 and increase organic flux) and the increased AW inflow influence in the medial and distal
848 biozones favoured the establishment of diversified foraminiferal communities able to occupy
849 different ecological niches and microhabitats (i.e., epifaunal and/or infaunal). In particular, the
850 phytodetritus indicator *Nonionellina labradorica* and the AW indicator *Adercotryma*
851 *glomeratum* were the representative species in the medial and distal biozone, respectively.
852 The comparison between the two size fractions highlighted the presence of different

853 foraminiferal assemblages in terms of species composition but similar foraminiferal patterns
 854 along the transect. The supplementary ecological information obtained from the small size
 855 assemblage was imprecise due the lack of knowledge regarding the ecological preferences
 856 for these species in modern environments. Ultimately, the variation of several environmental
 857 parameters in relation to the distance from the glacier terminus, parallelly to the appearance
 858 of different foraminiferal assemblages, suggests the potential investigation of diversity patterns
 859 in relation to the distance from the front as potential proxy for glacier retreat.



860

861 **Figure 8.** Conceptual model showing the environmental gradients created by tidewater glacier dynamics
 862 and, repartition of benthic foraminiferal communities and their microhabitat preferences.

863 **Supplementary materials**

864 Tables S1 and S2 and Figs. S1, S2, and S3 can be found in the Supplementary material.
865 Scanning electron micrographs (plates) of the most relevant species are shown in Figs. S4,
866 S5 and S6 in the Supplementary material.

867 **Author contributions**

868 EF: conceptualisation, data curation, formal analysis, investigation, methodology, validation,
869 visualisation, writing-original draft, writing-review & editing. MM, MPN and HH:
870 conceptualisation, funding acquisition, investigation, resources, supervision, validation,
871 writing-review & editing. AB: funding acquisition, resources, writing-review & editing. YP:
872 investigation, writing-review & editing. IB: methodology, writing-review & editing. MD:
873 methodology, writing-review & editing.

874 **Competing interests**

875 The authors declare that they have no conflict of interest.

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