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Biogeosciences Discussions

# *Interactive comment on* "Organic carbon rich sediments: benthic foraminifera as bio-indicators of depositional environments" *by* Elena Lo Giudice Cappelli et al.

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This study attempts to reveal benthic foraminiferal responses to organic carbon in fjords system. Previous studies have revealed that benthic foraminifera are useful proxies for various environmental factors, such as oxygen content and food supply in many field. Each voe may have each sediment system because their bottom topography, surrounding environment, and river and current systems are different. These differences control the distributions of grain size, organic carbon, and benthic foraminifera. However, detailed environmental factors of each voe are not described in the manuscript. The authors discuss the "unrestricted" or "restricted" geomorphology, but figure 1 is



quite small and detailed characteristics of each voe and sampling points are missing. There is no information about spatial distribution of grain size within each voe in Figure3, so it is difficult to evaluate the distribution. Figures of spatial distributions of grain size, organic carbon, and benthic foraminiferal assemblage can assist in understanding the data interpretation. Grain size is another important parameter controlling benthic foraminiferal distribution in marine environments. However, the authors omit the grain size data from discussion of benthic foraminifera vs. environmental parameters for the reason that grain size distributions don't show obvious trend. Complex factors affect the benthic foraminiferal distributions in shallow marine environments, so I strongly recommend that the authors perform statistical analysis concerning the relationship between benthic foraminifera and environmental parameters (not only carbon but also grain size, water depth, BWS, and DO: : :).

Following the referee's comments ,we have included (under the area of study section) a detailed description of available environmental parameters for each voe and modified Fig.1 to better represent the geomorphology of each sea loch (Page 3 lines 17 to page 4 line 18 and Fig. 1, additional info on soil types in Shetland are now illustrated in Suppl. Fig. 1). We modified Figs. 3 and 4 to better illustrate the spatial distribution of grain size, IC, OC and OM within each voe. We agree with the referee that grain size is an important parameter, generally co-varying with a number of other variables and therefore linked to foraminiferal distribution in marine environments; however, in our dataset we do not see this simple correlation, most likely because of the complexity of coastal systems compared to open marine settings. For example, Cibicides spp. occur in both fine and coarse sediments despite typically being a species that favours coarse substrates for its epilithic mode of attachment. To provide a more thorough representation of the relationship between benthic foraminiferal assemblage distribution and environmental parameters we performed on the full dataset (forams + 10 environmental parameters) canonical correspondence analysis including the % clay as one of the sedimentological parameters (Page 10 line 10 to page 11 line 3 and Figs. 3a and 4).

Introduction Pg 2 Line 24-28: The authors mention the TROX model of Jorissen et al. (1995). This model is mainly applied to the deep sea setting because of its relatively stable environment. As mentioned above, shallow marine environment is affected by various environmental factors, so it is difficult to apply the simple relationship.

Under the light of the referee's comment, we added that TROX models are typically used in deep-sea settings (Page 2 line 24) and that other environmental parameters like salinity and grain size distribution may be more variable and therefore affect the composition of benthic foraminiferal assemblages in shallow marine settings (par 4.3.5). This is further illustrated in Fig. 4.

Pg 3 Line 7 (also for pg 8 Line 31, title of section 4.3, and pg 13 Line 4): The authors use the term "biogeography", but I think this study in not biogeographical study. "distribution" is more adequate than "biogeography".

Changed into distribution pg.3 line 7 and recurrence.

Materials and methods Pg 3 Line 17: As mentioned above, the detailed descriptions of each voe should be included in the main body of manuscript.

Done. Page 3 line 17 to page 4 line 18.

Pg 3 Line 21-25: This part is methodology of foraminiferal analysis. I recommend to move this part to section 2.6.

Done. We revised paragraph 2.6 following the referee's recommendation and also the comments of Referee #2.

Pg 3 Line 22-23: Why do you consider that the method of Schönfeld et al. (2012) may lead to underrepresentation of living foraminifera and the method is problematic? The authors explain that the reason for analyzing total (live + dead) assemblage is underrepresentation of living foraminifera in this part. However, the authors mention that the reason is "to provide a tool for the interpretation of fossil foraminiferal assemblages and their relationship with changes in OM and OC content in sediments over time" in



page5, line 23-24.

We understand the referee's confusion and we have rephrased this part of the ms to clarify our points. We do not think that the method of Schoenfeld et al. (2012) may lead to underrepresentation of living foraminifera; what we meant is that scraping the top layer ($\sim$ 1 cm thick) of each grab with a domestic spoon may lead to a potential underestimation of living fauna if mixing of the top layer occurred when sampling. In this scenario, the number of living foraminifera at the sediment surface will be "diluted" due to the presence of dead/fossil specimens from deeper sediments. Having said this, a recent study by Rillo et al. (2019) reported that historical sediment samples collected in a way that could have caused disturbance of the sediment surface (sounding and dredge) are still representative of surface conditions and their foraminiferal assemblages can be used to reconstruct environmental changes reliably (Pg. 6 lines 18-29). The aim of this study is to provide a tool for the interpretation of fossil foraminiferal assemblages and their relationship with OC, therefore using total assemblages over living fauna is a more appropriate tool as total assemblages will better represent downcore fossil fauna found under comparable environmental conditions (revised par. 2.6).

Pg 3 Line 26-27: The authors don't mention BWT. Please describe also about BWT (Fig. 2a).

Done. Pg. 4 line 26.

Pg 4 Line 14: I think the detailed methodology of LOI analysis should be included in the main body of manuscript.

Done. Pg. 5 Lines 13-19.

Pg 6 Line 3: "Fig. 4" should be "Fig. 5".

Changed. Page 9 Line 16.

Results Pg 6 Line 26-27: TC data are not shown.

We changed Fig. 4 and TC data are now shown (Pg. 8 line 5 and Fig. 3d).

Pg 7 Line 5: The authors argue that high OC and low IC at the head of the voes, but I can't find this trend in figure 4a. Please also see comment below (comment to Pg 9 Line 2-6).

We agree with the referee and rephrased this part of the ms (Pg. 8 lines 10-11) and revised Fig. 4 (now Fig. 3). Due to the geomorphology and geometry of the voes, the pattern we observe in the distribution of OC and OM follows a proximity to land/freshwater input trend rather than a seaward gradient (Figs. 3d and 4).

Pg 7 Line 7, 8: The authors use "Quinqueloculina seminulum" in supplementary table.

Changed to seminula in Supplementary Table 1.

Pg 8 Line 3-4: Please add relative abundance after Cibicides spp. and E. scaber.

Done. Pg. 9 line 18.

Discussion Pg 9 Line 2-6: The authors argue that a seaward gradient is evident, but I don't agree this argument. First of all, the authors analyze only two stations in Olna Firth and Aith Voe, and three stations in Busta Voe. So, you can't discuss the gradient in these voes. In addition, it seems that samples from Vaila Sound are not collected along the environmental gradient (Fig. 1). Moreover, it seems that there is no obvious seaward gradient in Clift Sound and Sand Sound.

We agree with the referee and rephrased this part of the ms and revised Fig. 4. Due to the geomorphology and geometry of the voes (now better illustrated in Fig. 1), the pattern we observed in the distribution of OC and OM follows a proximity to land/freshwater input trend rather than a seaward gradient. We rephrased the discussions accordingly (par 4.2).

Pg 9 Line 18-22: The authors argue that the high TC content at MD 15-05 is the effect of oil spill. If so, benthic foraminifera may change in response to the effect. Lei et



al. (2015_Marine Pollution Bulletin) suggest that E. scaber is indicator of oils. Your foraminiferal data don't show the effect of oil or high TC.

We agree with the referee that foram assemblages should reflect the oil spill; it was just a speculation given the surprisingly high levels of OC at this location – not reflected in the Cibicides dominated assemblages. We revised this speculation and left an open question regarding what could be driving the high TC content at station MD15-05 (Pg. 11 lines 21-28).

References: Some articles are overlooked in references. Soil Survey of Scotland, 1981 Alve, 1994 Alve, 1995 Alve and Nagy, 1986 Qvale et al., 1984

Fixed.

Figure 1: Please add space between "Sand" and "Sound". As mentioned above, figure 1 is quite small and detailed characteristics of each voe and sampling points are missing.

Changed. Fig. 1.

Figure 2: Please add legends for each profile (i.e. please add "station number").

Done. Fig.2.

Figure 3: Please add legends for each plot (i.e. please add "station number"). It is difficult to identify the relationship between data and sampling point. I think figure 3b is not needed because the data are not discussed enough in the manuscript.

We substantially revised Fig. 3 to include the referee's suggestions, also based on previous comments.

Figure 4: Distance of OCterr of Aith Voe (left one) don't match with OC and LOM. Third plot from the right (Clift Sound) is missing in figure of OCterr. We substantially revised Fig. 4 to include the referee's suggestions, also based on previous comments.

This info in now in the revised Fig. 3.

Figure 5: What are “Head” and “mouth” in the figure of Ammonia? Do you mean horizontal axis of MDS is gradient from head to mouth? Fig. 5-9 is Cibicidoides, but the authors use Cibicides in the text. The authors mention that “we grouped under the name E. excavatum both forma selseyense and forma clavata: : :”, but “selseyensis” is used in figure 5-7. There is no indication of legend unit. Please add the unit (%?). There are no indication about four circled groups, so please add the name of each group near the dashed circles. It would be better to move SEM figures close to each MDS plot.

We revised Fig. 5 to include the above suggestions; however, it was not possible to include the SEM figure close to each MDS plot due to legibility issues. Foram nomenclature is now consistent throughout the revised manuscript.

Supplementary Material: I can’t find supplementary figures, so I can’t evaluate supplementary figure 1 and 2.

We apologise for the missing supplementary material. There must have been a problem when we uploaded those files and we were not aware they were missing. We have now included both supplementary figures.

The authors use “Fig. 1a” in supplementary material, but figure 1 is single figure. The authors describe “the island of Vaila” and “the isle of Linga”, but I can’t identify the islands because there are no indication of these islands in figure 1.

We revised Fig. 1 to better illustrate the geometry and geomorphology of each voe.

Supplementary Table 1: The authors use Cibicidoides, but “Cibicides” is used in the text. Oolina mellow should be Oolina melo. Trochamina sp. should be Trochammina sp.. There are blanks only in the column of Reophax fusiformis. There is “0.0” in the gray cell of Reophax fusiformis. Please add picked number of specimens in table 1.

We revised Supplementary Table 1 following the referee’s remarks. Upon acceptance



of this ms, the full dataset will be made available on PANGEA.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2019-125/bg-2019-125-AC1-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2019-125, 2019.

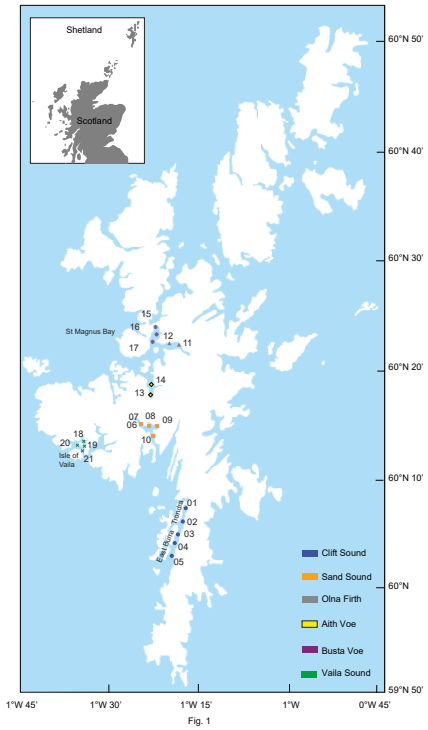
Shetland
Scotland
St Magnus Bay
Isle of Vaila
East River Tunnel
Clift Sound
Sand Sound
Olna Firth
Aith Voe
Busta Voe
Vaila Sound
60°N 50'
60°N 40'
60°N 30'
60°N 20'
60°N 10'
60°N
59°N 50'
1°W 45'
1°W 30'
1°W 15'
1°W
0°W 45'
Fig. 1

**Fig. 1.**



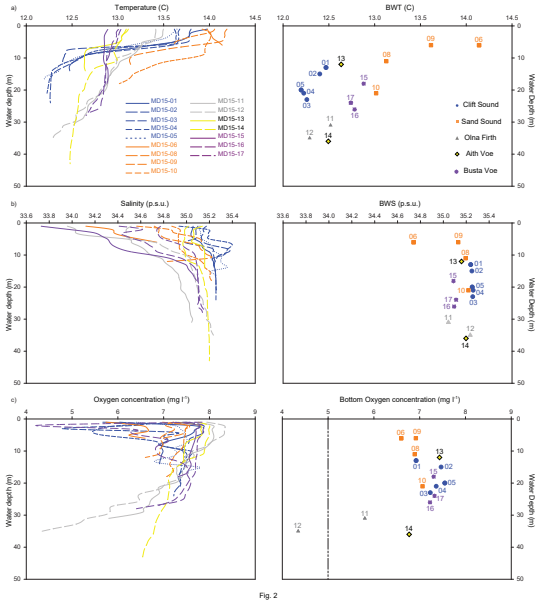
Temperature (C)
BWT (C)
Salinity (p.s.u.)
BWS (p.s.u.)
Oxygen concentration (mg l⁻¹)
Bottom Oxygen concentration (mg l⁻¹)
Water depth (m)
Water Depth (m)
Clift Sound
Sand Sound
Olna Firth
Aith Voe
Busta Voe
Fig. 2

**Fig. 2.**

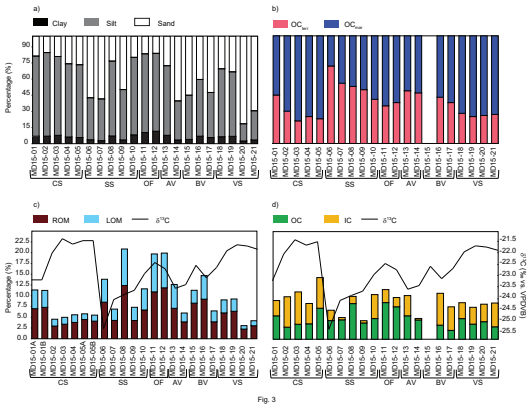


Fig. 3

**Fig. 3.**



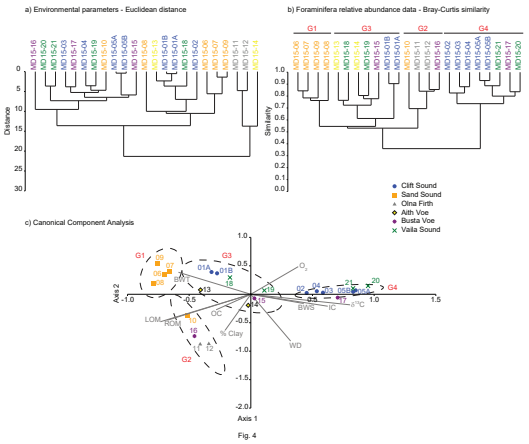


Fig. 4

**Fig. 4.**

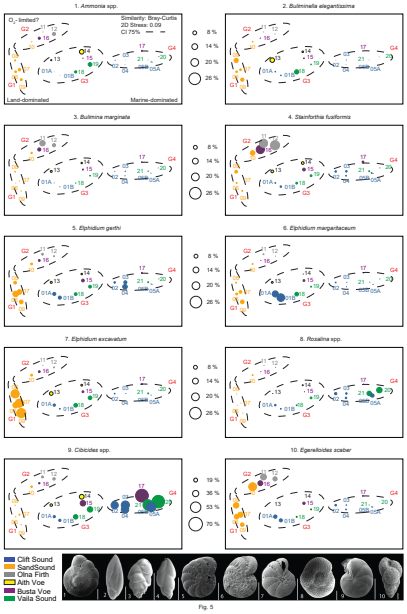
1. Ammonia spp.
2. Bulliminella elegantissima
3. Bulimina marginata
4. Stainforthia fusiformis
5. Elphidium gerthi
6. Elphidium margaritaceum
7. Elphidium excavatum
8. Rosalina spp.
9. Cibicides spp.
10. Egerelloides scabar
Clift Sound
SandSound
Olna Firth
Ath Voe
Busta Voe
Valla Sound

**Fig. 5.**



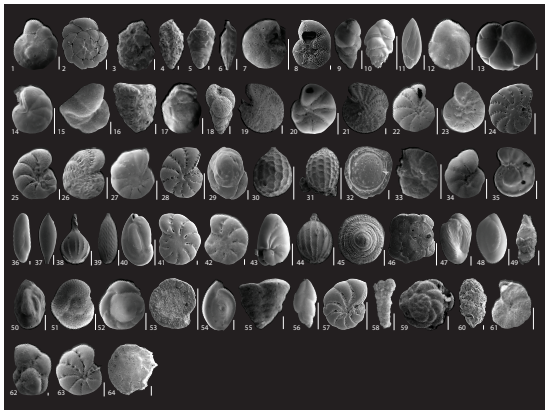

**Fig. 6.**