

## ***Interactive comment on “Stable isotope signatures of Holocene syngenetic permafrost trace seabird presence in the Thule District (NW Greenland)” by Sebastian Wetterich et al.***

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Responses from the authors to comments of anonymous Referee #1 - bg-2019-71

The manuscript by Wetterich et al. is an interesting attempt of evaluation of the role of seabird as a factor controlling Arctic tundra development. It try to link seabird colonization with climate change over the last 5,000 yrs. The manuscript is well written, easy to read and understand. However, I would ask for some more explanation and small correction, mainly concerning sediment dating and presentation of analytical results. REPLY: We are grateful to referee #1 for the time and effort spent on reviewing our manuscript.

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1. The radiocarbon dating and age-depth modeling could be describe more detail. I know, that it was a topic of paper by Davidson et al. 2018, but still I have some doubts: Some samples for dating were collected from significantly thick core segments (even 10 cm long for topmost part of SI 1). Do author consider depth uncertainty in age-depth models? It can be significant.

REPLY: All dated samples derive from high-resolution sampling of 4- to 5-cm thick core segments given the amount of material needed for the various analyses. The only exception is the mentioned sample from the uppermost SI1 core that represents the 10-cm-thick active layer with an expected recent age of 51 cal yr BP. Here, in the uppermost thawed cover, more detailed subsampling seems inappropriate. Therefore depth uncertainty in the age-depth models is of minor relevance for the present core records. The complete presentation of the age-depth models from Davidson et al. (2018) can be found as Supplementary Material here: [https://static-content.springer.com/esm/art%3A10.1007%2Fs13280-018-1031-1/MediaObjects/13280\\_2018\\_1031\\_MOESM1\\_ESM.pdf](https://static-content.springer.com/esm/art%3A10.1007%2Fs13280-018-1031-1/MediaObjects/13280_2018_1031_MOESM1_ESM.pdf)

Please give some details on geological settings. According to my knowlage, at least in Saunders Is there is a lot of carbonate rocks. It could substantially impact radiocarbon dating ('old carbon effect'), since bulk sediment/peat samples were dated. How did the authors did overcome this issue?

REPLY: Indeed, according to Kurtz (1950) Saunders Island is mainly composed of siltstones, shales and dolomite of the Narssârssuk formation, which is described by Dawes (2006) to be composed of pale carbonates and siliciclastic redbeds of the Narssârssuk Group. Although carbonatic rock is present in the study area we leave out of account its potential impact on the selected peat mosses, which were radiocarbon-dated in the present study, as described in detail by Davidson et al. (2018). We did not date bulk sediment samples.

What sediment/rocks were in the cores' basement? Are peat profile represent entire

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biogenic sedimentation on the spots?

REPLY: This concern was also raised by ref#2. We stopped drilling when we hit boulders, larger than the drill tube diameter, whose density we assume to increase at the transition between the overlying peat and the underlying bedrock. We therefore assume the lowermost (oldest) peat to be close to the bedrock surface. Thus, we almost captured the entire peat profile at the given location, although we did not probe the bedrock basement. We added the following specification to section 3.1: “Extensions were used to reach deeper deposits until the corer hit boulders, larger than the drill tube diameter, whose density increased at the transition between the peat and the underlying bedrock.”

2. How were the cores divided into zones/periods? What were the criteria? Was the division evaluated with statistical analysis (is it significant?)

REPLY: We added to section 3.3 the following information: “The zonation of the cores was deduced from obvious changes in the accumulation rates.”

3. Please give more detail on subfossil Testacea analysis methodology, namely how big samples were taken to analysis, counted quantities etc. I would see ‘classical’ percentage diagrams rather.

REPLY: We added the following information to section 3.4: “Samples of about 1 g (dry weight) for testacean analysis were suspended in purified water and wet-sieved through a 500- $\mu\text{m}$  screen.” The general agreement is that direct counting recovers from a sample only a certain fraction of species diversity. Thus, higher numbers of identified specimens per sample enlarge the probability that all species present in the assemblage are captured. However, in testacean research, this approach entails an enormous effort for samples with low shell density. The standard quantity of observed individuals customary in protistology is 160 specimens, but this amount is not applicable to all fossil communities. The quantity, i.e. the number of observed testacean individuals, depends on the original community species richness, on the presence of

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dominant species and species abundance structure, on the density of testacean organisms in the soil, and on the amount of shells damaged owing to fossilisation processes. Also, patchy distribution of testate amoebae reflecting habitat heterogeneity may affect the process of recovering species. In fossil samples with poor testacean density, the interpretation focuses on the ecological groups combining species with similar requirements in habitat and environmental conditions. Due to low shell densities in the studied cores, we chose this approach, leading to the presentation of ecological groups in Figures 4 and 5 and cautious interpretation of these records in section 5.1. A percentage diagram seems useless due to the low count numbers per sample. We added the count number as Supplementary Material (Tables S1 and S2) and the following information to section 3.4: “Count numbers of testacean shells per sample were generally low (Tables S1 and S2). Thus, the interpretation is cautiously based on the ecological groups combining species with similar requirements under specific habitat and environmental conditions.”

4. The values presented in the Table 2 (results for food and faeces) cannot have uncertainty 0.0. Please report at least measurement uncertainties. I hope, that in means calculation authors include measurement uncertainty and applied ‘error propagation rule’ for mean uncertainty calculations.

REPLY: We deleted the standard deviation of  $\pm 0.0$  for those samples where only one measurement was undertaken ( $n = 1$ ) from Table 2. The analytical accuracies of the respective methods are given in section 3.3 where we added the following information: “The OM analyses of the modern source material (bird’s food and faeces samples, Table 2) were undertaken at the UC Davis Stable Isotope Facilities, California, USA, whose lab procedures are described in detail at <https://stableisotopefacility.ucdavis.edu/>. The long-term standard deviation is 0.2 ‰ for  $\delta^{13}\text{C}$  and 0.3 ‰ for  $\delta^{15}\text{N}$ .” For the modern reference and core data (per core zone and for the entire core) we applied once the calculation of mean values and standard deviations as presented in Table 2 to capture the data range for comparison. Propa-

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gation of uncertainty is un-applicable because the mean values were not included in further calculations.

Table 2: in row all GL zones should be '4400 to 540'

REPLY: Changed accordingly.

Page 1, row11: 'ground at sea' sounds tricky, consider change to 'area'

REPLY: Changed accordingly.

Page 5, row2: please report accuracy in %.

REPLY: Changed accordingly.

References to our replies Davidson, T.A., Wetterich, S., Johansen, K.L., Grønnow, B., Windirsch, T., Jeppesen, E., Syvyränta, J., Olsen, J., González-Bergonzoni, I., Strunk, A., Larsen, N.K., Meyer, H., Søndergard, J., Dietz, R., Eulears, I., Mosbech, A.: The history of seabird colonies and the North Water ecosystem: Contributions from palaeoecological and archaeological evidence, *Ambio*, 47 (Suppl 2), 175-192, 2018. Dawes, P.R.: Explanatory notes to the Geological map of Greenland, 1:500000, Thule, Sheet 5, Geological Survey of Denmark and Greenland Map Series 2, 97 pp. + map. GEUS Copenhagen, Denmark, 2006. Kurtz, V.E.: Geology of the Thule area, Greenland. *Proceedings of the Oklahoma Academy of Science*, 31, 83-89, 1950.

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Table S2 Table S2: Testacean specimen counts per sample from the Apat core (S1), including an ecological indication of the different taxa.

Depth interval [cm bs]	core S11	
0-10		
10-13	1	Centropyxis aerophila
13-22	1	Centropyxis aerophila v. minuta
22-25	4	Centropyxis constricta
34-38	5	Centropyxis constricta v. minima
42-46	6	Centropyxis sylvatica
52-56	2	Centropyxis sylvatica v. minor
66-72	1	Cyclopyxis eurystoma
72-76	1	Cyclopyxis eurystoma v. parvula
80-84	1	Plagiopyxis cf. callida
86-92	1	Trinema lineare
92-100	2	Arcella arenaria v. compressa
104-110	1	Nebela tinctoria
115-120	1	Arcella discoides var. difficilis
126-132	1	
136-140	3	
140-148	3	
150-154	3	
168-172	3	
176-180	1	
192-198	1	
	17	number of specimens
	6	number of taxa

Fig. 2. Table S2