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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.

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 uncertinity 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

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 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-μm 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

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 δ13C and 0.3 ‰ for δ15N." 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. Propagation 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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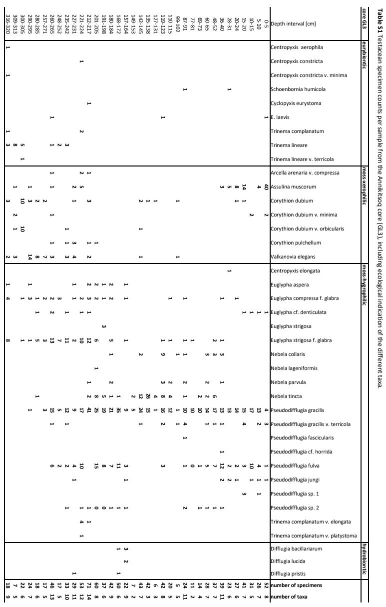

Table S1 Testacean specimen counts per sample from the Annikitsoq core (GL3), including ecological indication of the different taxa.

core GL3	eurybiontic									moss-xerophilic						
Depth interval [cm]	Centropyxis aerophila	Centropyxis constricta	Centropyxis constricta v. minima	Schoenbornia humicola	Cyclopyxis eurystoma	E. laevis	Trinema complanatum	Trinema lineare	Trinema lineare v. terricola	Arcella arenaria v. compressa	Assulina muscorum	Corythion dubium	Corythion dubium v. minima	Corythion dubium v. orbicularis	Corythion pulchellum	Valkanovia elegans
0-5						1					40		2			
5-10											4					
10-15													2			
15-20											14	1				
20-24											8	1				
28-31				1							5					
36-40											3					
48-52																
60-65																
69-73																
77-81																
87-91				1												
99-102												1				1
110-115																
119-123						1										
127-131												1				
135-138												1				
142-145												2		1		1
149-153																
157-164																
168-172																
180-184																
191-198																
201-205															1	
212-217					1					1		3			1	2
221-224		1					2			2	5					
227-231											2	1			3	4
235-242								3						1	1	3
248-252								2								
260-265						1		1		1	1		1		1	3
257-271												2				7
280-285												2				8
290-295											1	3				14
300-305								5	1			10		10		
309-313								8			1		2	1		3
316-320	1		1				1	3				3				2

core GL3	moss-hygrophilic									
Depth interval [cm]	Centropyxis elongata	Euglypha aspera	Euglypha compressa f. glabra	Euglypha cf. denticulata	Euglypha strigosa	Euglypha strigosa f. glabra	Nebela collaris	Nebela lageniformis	Nebela parvula	Nebela tincta
0-5				1						
5-10				1						
10-15				1						
15-20				1						
20-24			1							
28-31	1									
36-40			1			1	3		1	
48-52						2	3			6
60-65							3		2	2
69-73										2
77-81						1				
87-91			1			1	1		2	1
99-102							1			
110-115			1			1			2	4
119-123						1	9		3	8
127-131										4
135-138										26
142-145							2			12
149-153										2
157-164		1	1			1				
168-172										1
180-184		2	2			5	1		2	1
191-198		1	1		3					5
201-205		2	2			6		1		8
212-217		2	3	1		12			1	2
221-224			2	1		10				
227-231		1	1			2				
235-242				1		11				
248-252			3			7				
260-265			2	2		13				
257-271			2			3				
280-285			1	1		5				1
290-295		1	3			1				
300-305			1			1				
309-313										
316-320		1	4			8				

core GL3	moss-hygrophilic									
Depth interval [cm]	Pseudodifflugia gracilis	Pseudodifflugia gracilis v. terricola	Pseudodifflugia fascicularis	Pseudodifflugia cf. horrida	Pseudodifflugia fulva	Pseudodifflugia jungi	Pseudodifflugia sp. 1	Pseudodifflugia sp. 2	Trinema complanatum v. elongata	Trinema complanatum v. platystoma
0-5	4	3			1	1				
5-10	13	2			4	1	1			
10-15	17				10	1				
15-20	15	4			3		3			
20-24	14				2	1				
28-31	13				2	2				
36-40	13	1		1	12	2		1		
48-52	17	1			7			1		
60-65	14	1			5			1		
69-73	10				1			1		
77-81	10				0					
87-91	10	4	1		1			2		
99-102	1	1								
110-115	12									
119-123	16	2			3					
127-131	1									
135-138	15									
142-145	24	1								
149-153	5									
157-164	9				3	1		1		
168-172	35				11			1		
180-184	21				7			1		
191-198	19				8			0		
201-205	25				15			0		
212-217	41							1	1	
221-224	17				10			1	4	1
227-231	9				4	1				
235-242	12	1			2			1		
248-252	5				2					
260-265	15	1			6					
257-271	3									
280-285										
290-295	1									
300-305										
309-313										
316-320										

core GL3	hydrobiontic				
Depth interval [cm]	Difflugia bacillariarum	Difflugia lucida	Difflugia pristis	**number of specimens**	**number of taxa**
0-5				52	8
5-10				26	7
10-15				31	5
15-20				41	7
20-24				27	6
28-31				23	6
36-40				39	11
48-52				37	7
60-65				28	7
69-73				14	4
77-81				11	2
87-91				24	11
99-102				5	5
110-115				20	5
119-123				42	8
127-131				6	3
135-138				42	3
142-145				43	7
149-153				7	2
157-164	3	2		22	9
168-172	1		1	50	6
180-184				42	9
191-198				37	6
201-205				60	8
212-217				71	14
221-224				53	12
227-231			1	29	11
235-242				33	10
248-252				17	5
260-265				46	13
257-271				17	5
280-285				18	6
290-295				24	7
300-305				22	6
309-313				7	5
316-320				18	9

Fig. 1. Table S1

Table S2 Table S2 Testacean specimen counts per sample from the Appat core (SI1), including an ecological indication of the different taxa.

core SI1	Eurybiontic										moss-xerophilic	moss-hygrophilic	hydrobiontic		
Depth inverval [cm bs]	Centropyxis aerophila	Centropyxis aerophila v. minuta	Centropyxis constricta	Centropyxis constricta v. minima	Centropyxis sylvatica	Centropyxis sylvatica v. minor	Cyclopyxis eurystoma	Cyclopyxis eurystoma v. parvula	Plagiopyxis cf. callida	Trinema lineare	Arcella arenaria v. compressa	Nebela tincta	Arcella discoides var. difficilis	**number of specimens**	**number of taxa**
0-10	**1**	**1**		**10**		**4**		**6**			**2**			**24**	**6**
10-13	**1**		**4**		**6**	**2**		**1**			**3**			**17**	**6**
19-22			**1**		**1**	**1**	**1**							**4**	**4**
26-30					**7**					**1**				**8**	**2**
34-38			**1**		**1**		**1**	**1**						**4**	**4**
42-46			**1**											**1**	**1**
52-56					**1**			**1**			**1**			**3**	**3**
64-68					**1**		**1**	**1**						**3**	**3**
72-76			**1**		**1**									**2**	**2**
80-84					**1**		**3**		**1**					**5**	**5**
88-92					**1**									**1**	**1**
96-100			**1**		**1**						**1**			**3**	**3**
103-107			**1**		**3**		**1**							**5**	**3**
115-120			**3**		**3**						**1**			**7**	**3**
128-132					**1**									**1**	**1**
136-140			**5**		**1**									**6**	**2**
144-148	**1**		**3**	**1**	**1**		**3**				**3**			**12**	**6**
150-154	**1**		**1**								**1**			**3**	**3**
168-172						**1**								**1**	**1**
176-180			**1**								**1**			**2**	**2**
195-198												**1**	**1**	**2**	**2**

Fig. 2. Table S2