Supplementary material for:

Extending planktic foraminiferal Mg/Ca palaeothermometry into polar temperature ranges: crust- and lamellae specific calibrations and non-thermal controls

Adele Westgård*, Mohamed M. Ezat, Freya E. Sykes, Julie Meilland, Thomas B. Chalk, J. Andy Milton, Melissa Chierici, Gavin L. Foster

*Correspondence to: adele.westgard@uit.no

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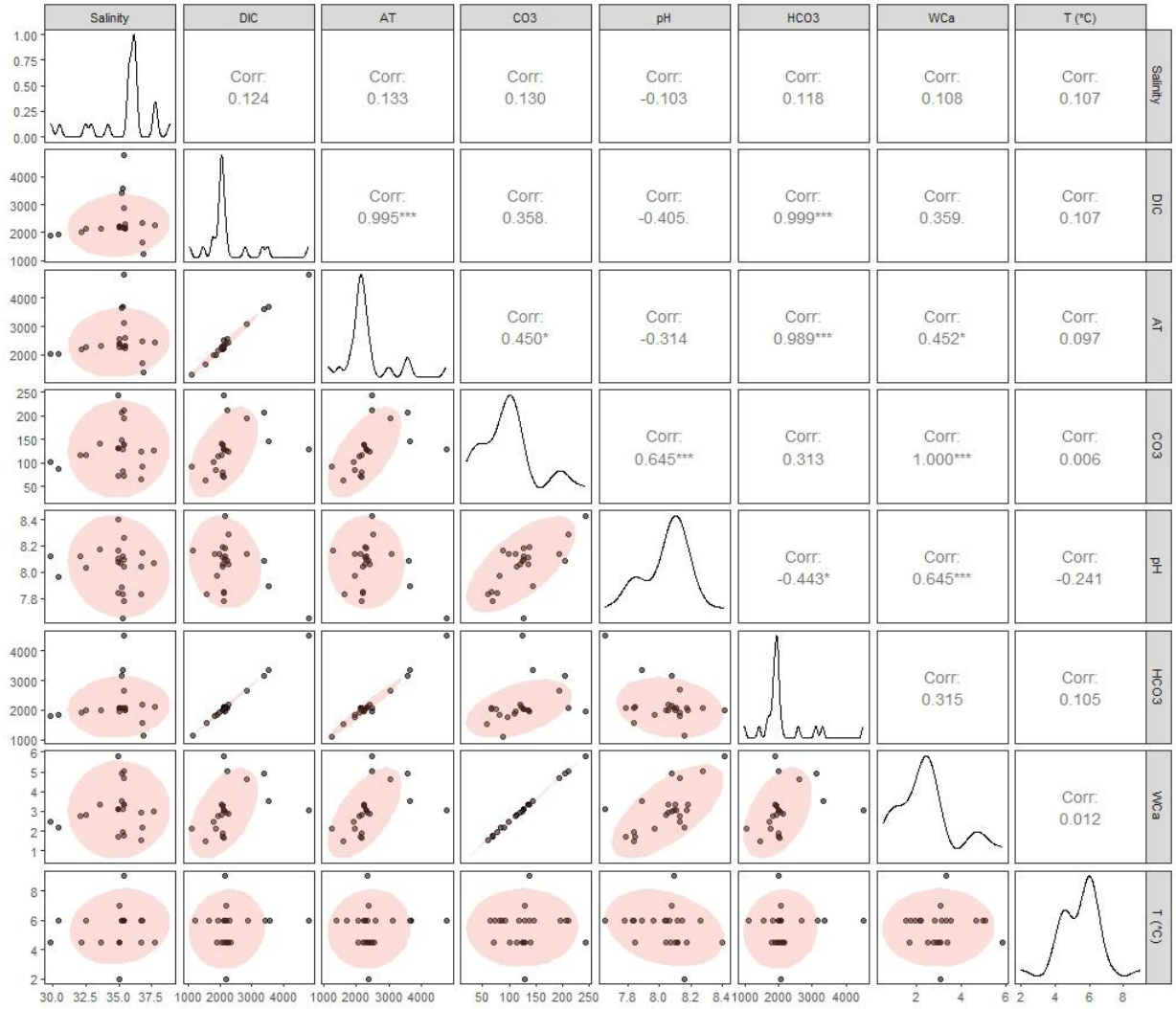

*Figure S1. Scatter matrix of culture media parameters for each water treatment. "Corr" refers to the correlation coefficient. ***p<0.001, **p<0.01, *p<0.05, .p<0.1.*

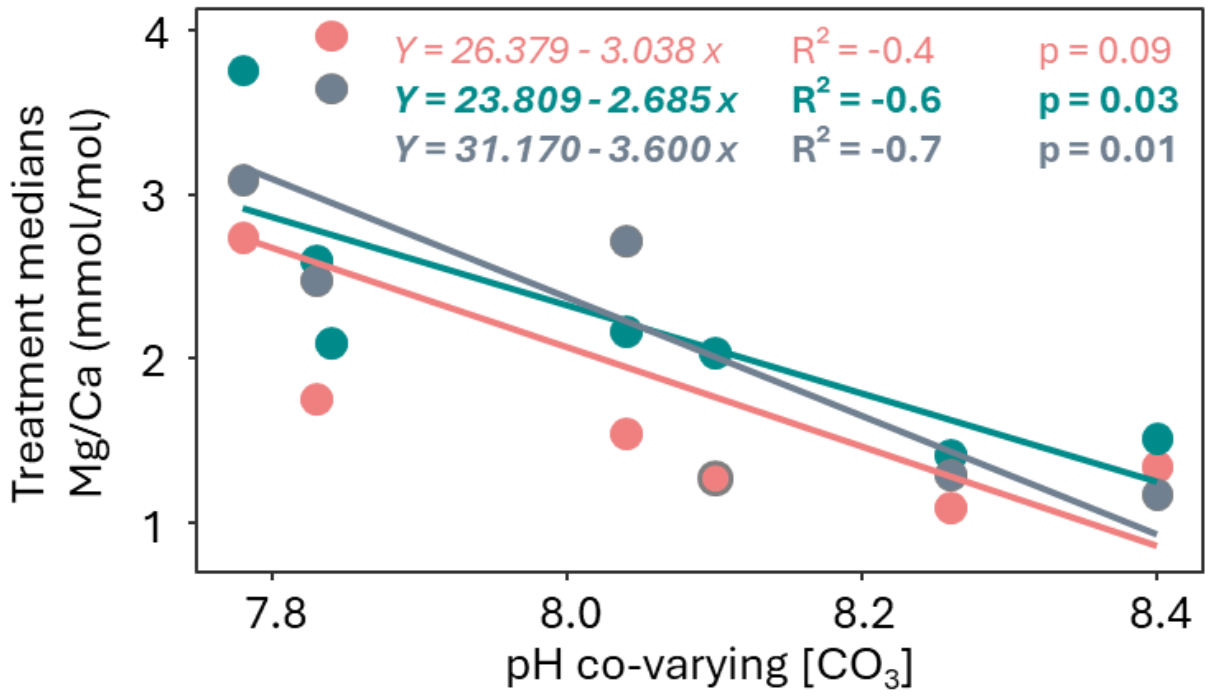

Figure S2. Mg/Ca (mmol/mol) correlated to pH with co-varying [CO_3^{2-}] (µmol/kg_{sw}), with 2022 treatments cultured at 6°C normalised to 4.5°C (2021 ambient temperature). Statistically significant ($p<0.05$) relationships are emphasised in bold writing.

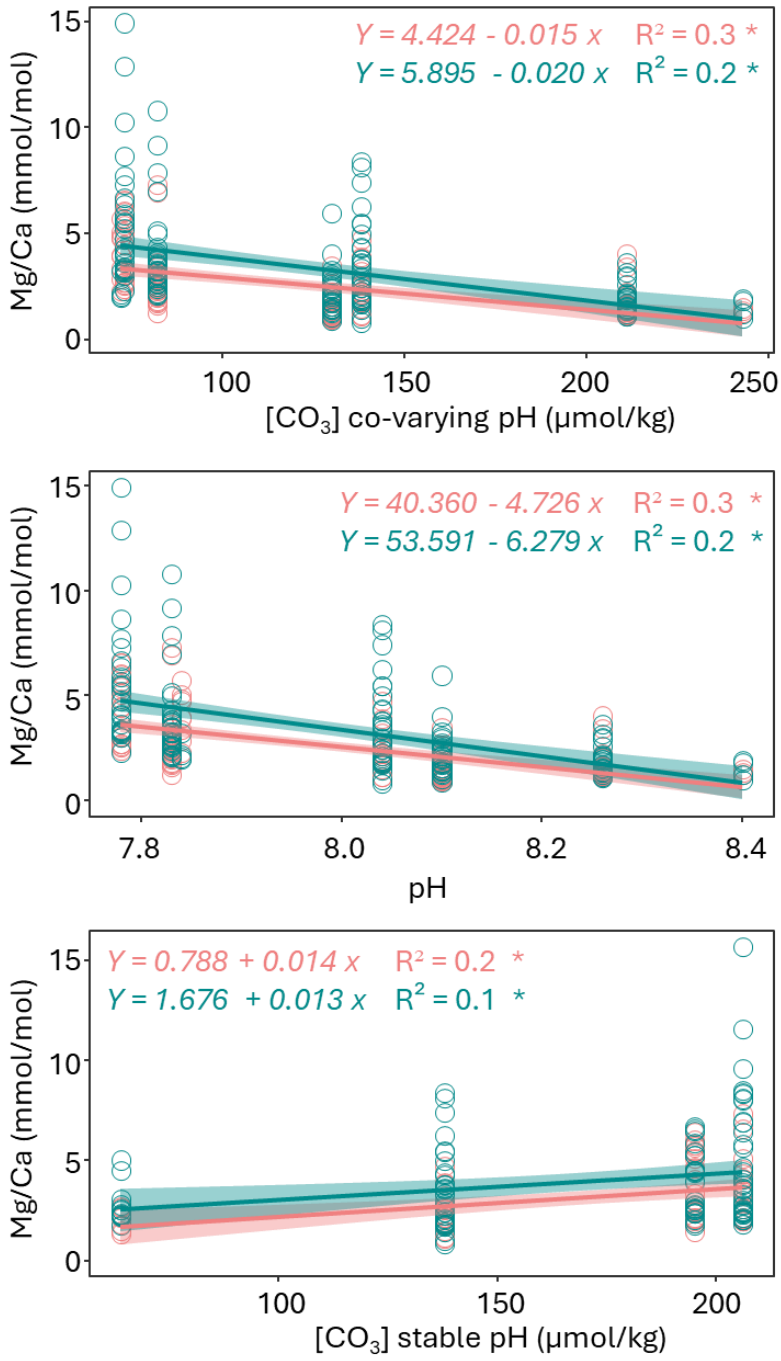

*Figure S3. Decoupling the Mg/Ca-carbonate chemistry relationship. Mg/Ca (mmol/mol) compared to $[CO_3^{2-}]$ ($\mu mol/kg_{sw}$) (top) and pH (middle) in N. pachyderma from the pH treatment with co-varying $[CO_3^{2-}]$. Bottom panel: Mg/Ca (mmol/mol) compared to $[CO_3^{2-}]$ ($\mu mol/kg_{sw}$) when pH is kept stable. *$p<0.05$.*

Table S1. Overview of published results from each experiment.

Treatment		*Year*	Westgård et al. (2023)	Westgård et al. (2026)	This study
Temperature (ºC)	2	2021	X		X
	4.5	2021	X	X	X
	6	2022		X	X
	7	2021	X		X
	9	2022		X	X
salinity	29.8	2021	X		X
	30.4	2022			X
	32.1	2021	X		X
	32.5	2022			X
	33.6	2021	X		X
	36.7	2021	X		X
	36.7	2021	X		X
pH and carbonate ion (pH total scale)	7.78	2022			X
	7.83	2022			X
	7.84	2021	X		X
	8.26	2022			X
	8.4	2021	X		X
Carbonate ion (µmol/kg)	64	2022			X
	195	2022			X
	206	2022			X
pH (decoupled carbonate ion)	7.65	2022			X
	7.88	2022			X
	8.15	2022			X
Published results			Discussions of biological observations of cultured *N. pachyderma*. No geochemical (element/Ca) data are included.	Presents a novel method for separating crust and lamellar calcite geochemically. Discusses element/Ca differences between crust and lamellar calcite based on means from 3 culture treatments.	Presents Mg/Ca– environmental relationships, including separate crust- and lamellar temperature calibrations. Discusses shell structure and biomineralisation in relation to environmental conditions. Includes data from 23 culture treatments.

Table S2. Mg/Ca_{sw} in mmol/mol of culture media. Seawater (final row) was sampled from 50 m depth at the foraminifera collection site in year 2021.

Variable	*Treatment*	*Year*	*Mg/Ca (mmol/mol)*
Temperature (ºC)	2	2021	4711 ±25
	4.5	*2021	4711 ±25
	6	*2022	5117 ±248
	7	2021	4711 ± 25
	9	2022	5117 ±248
salinity	29.8	2021	5208 ±36
	30.4	2022	4977
	32.1	2021	5174 ±55
	32.5	2022	4810
	33.6	2021	5262 ±43
	36.7	2021	5263 ±35
	36.7	2021	5248 ±53
pH and carbonate ion (pH total scale)	7.78	2022	4995
	7.83	2022	5126
	7.84	2021	5179
	8.26	2022	5192
	8.4	2021	5368 ±108
Carbonate ion (µmol/kg)	64	2022	4995
	195	2022	5130
	206	2022	4956 ±73
pH (decoupled carbonate ion)	7.65	2022	4951 ±175
	7.88	2022	4951
	8.15	2022	4923
average		**2021**	**5084** ±249
average		**2022**	**5024** ±107
Filtered seawater		2021	4788 ±102

Table S3. Overview of number of N. pachyderma chambers grown in culture per treatment, the number of specimens with crust or lamellae only analysed, with both components analysed and the total number of chambers that grew crust in the lab. The two final columns show the average %crust per treatment and average shell wall thickness (µm) in chambers where both crust and lamellae were analysed. CC+LC = both components.

Variable	Treatment	N chambers	N 100% crust	N 100 % lamellae	N CC+LC	N crusted	% crust (if both present)	Thickness (µm, if both present)
Temperature (ºC)	2	13	6	3	4	10	73	11
	4.5	38	9	12	17	26	62	17
	6	46	14	28	4	18	71	13
	7	13	8	3	2	10	60	12
	9	21	5	12	4	9	54	25
Salinity	29.8	5	2	2	1	3	87	24
	30.4	11	4	2	5	9	68	13
	32.1	6	2	0	5	3	76	14
	32.5	29	9	18	2	11	72	7
	33.6	10	5	0	5	10	68	15
	36.7	23	6	2	5	11	67	13
	36.7	6	1	0	5	6	57	14
pH and carbonate ion (pH total scale)	7.78	33	6	13	14	20	59	13
	7.83	45	11	19	15	26	58	12
	7.84	12	8	3	1	9	56	11
	8.26	28	6	12	10	16	62	14
	8.4	6	2	3	1	3	67	10
Carbonate ion (µmol/kg)	64	19	6	12	1	7	53	13
	195	45	19	21	5	24	66	11
	206	50	12	33	6	18	62	12
pH (decoulped carbonate ion)	7.65	28	5	22	1	6	63	8
	7.88	28	6	13	9	15	69	11
	8.15	10	2	1	7	9	37	23
Total		**525**	**154**	**234**	**129**	**279**		
Average		**23**	**7**	**10**	**6**	**12**	**64**	**14**

Table S4. Corrected Mg/Ca (mmol/mol) treatment medians corresponding to Fig. 5 and S2. All treatments cultured at 6°C are corrected for temperature, salinity treatments are also corrected for deviations of pH and/or [CO_3^{2-}] outside of standard error (pH ±0.05 and [CO_3^{2-}] ±12). See table 3 for measured Mg/Ca and table 2 for culture conditions. Crust (CC), lamellar calcite (LC), and both components combined (CC+LC) are listed separately.

Variable	Treatment	Mg/Ca (mmol/mol)			Corrected for
		CC+LC	CC	LC	
pH and carbonate ion (pH total scale)	**7.78**	3.09	2.74	3.76	Temperature
	7.83	2.48	1.76	2.60	Temperature
	8.04	2.72	1.55	2.17	Temperature
	8.26	1.30	1.10	1.42	Temperature
Salinity	**29.80**	2.15	1.88	2.34	[CO_3^{2-}]
	30.40	1.20	1.73	2.41	pH, [CO_3^{2-}], Temperature
	32.10	2.10	1.97	2.32	[CO_3^{2-}]
	32.50	1.55	1.64	1.39	pH, Temperature
	33.60	2.44	2.13	3.07	pH, Temperature
	35.40	2.19	1.31	1.68	pH
	36.70	3.53	3.70	3.01	pH
	36.70	1.98	1.67	2.30	