Supplementary Information for
Alkalinity-enhanced artificial substrates modulate local pH and increase survivorship of early-stage coral recruits

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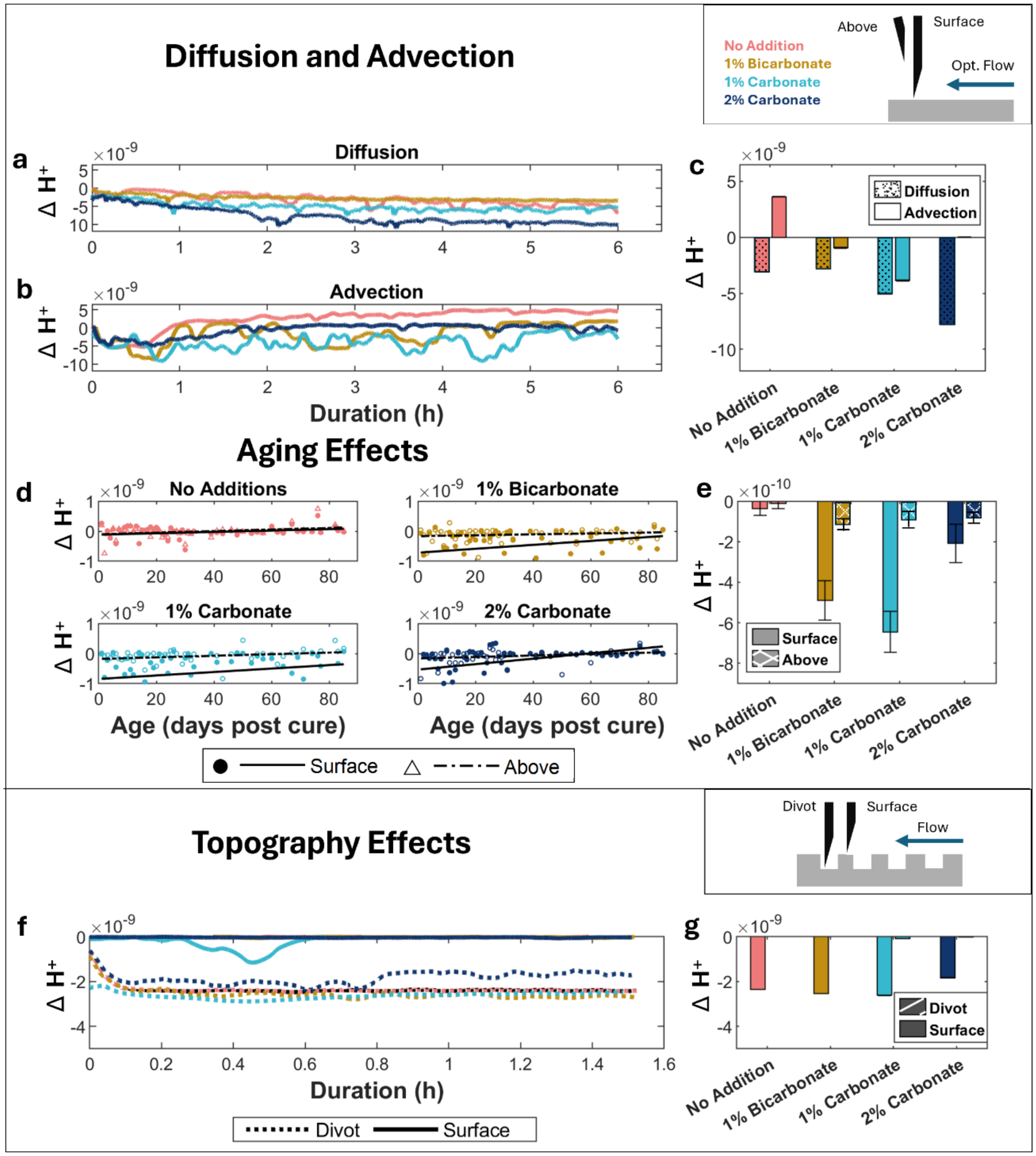

Figure 1. Physicochemical characteristics of AE tiles (ΔH^+)**.** (a) The first 6 h of a 24 h diffusion time series for flat tiles. (b) The first 6 h of a 24 h advection time series for flat tiles. (c) The average ΔH^+ from hour 1-6, after the tile reaches equilibrium with the environment. (d) Linear regressions fitted to ΔH^+ for tiles with no additions, 1% bicarbonate additions, 1% carbonate additions, and 2% carbonate additions, at the surface and 3.26 $\pm$ 0.09 mm above the surface of the tile to capture changes on the surface of the tile and within the laminar boundary layer in flow conditions. (e) Average ΔH^+ at and above the boundary layer of the four different chemistries throughout the 84-day aging experiment. Asterisks indicate average value greater than 0. (f) The first 90 min of advective time series on textured tiles measured at the surface of the tile and within a divot on a textured tile. (g) The average ΔH^+ over the duration of the advective time series for textured tiles.

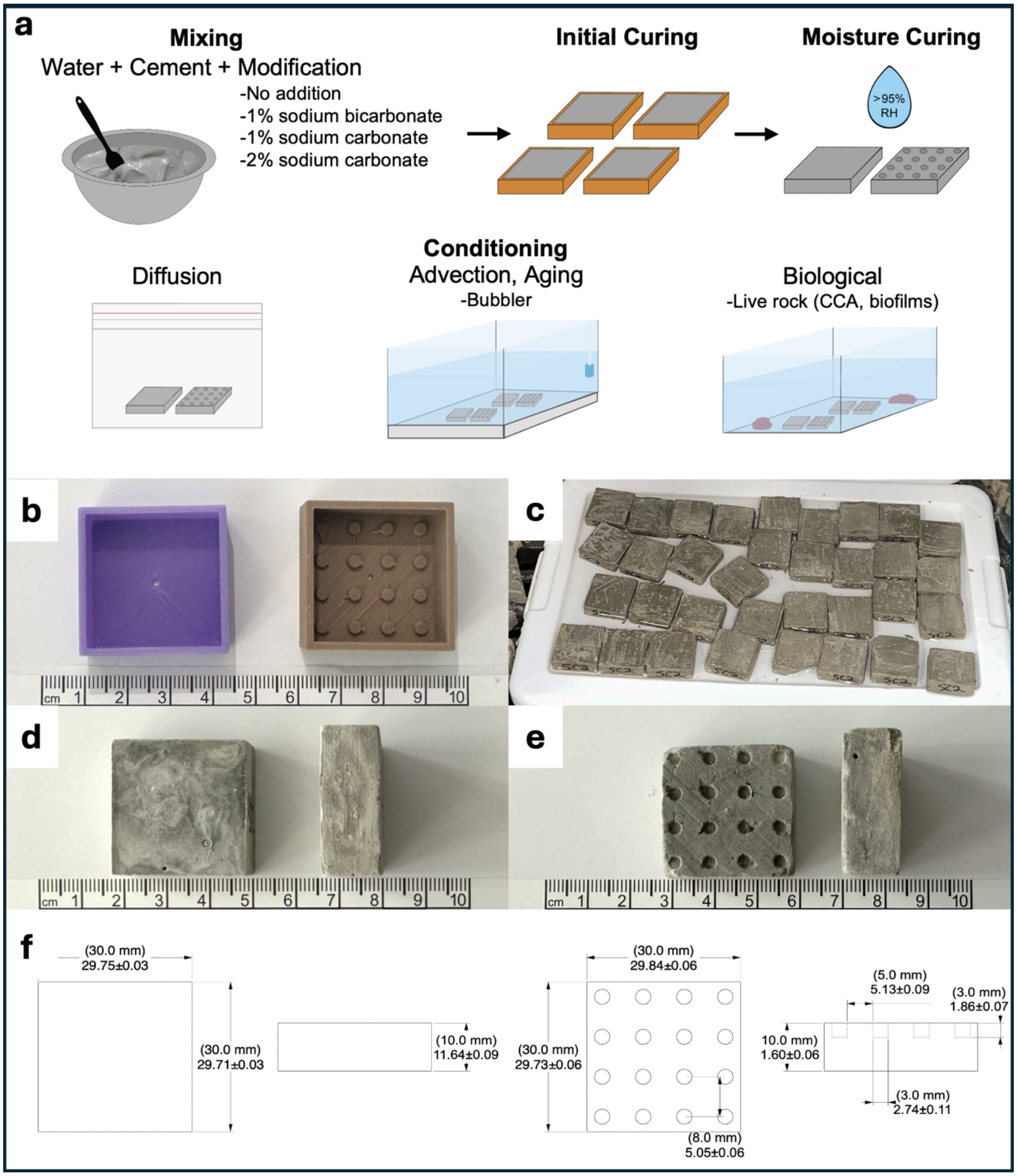

Figure 2: AE Tile fabrication methods. (a) Cartoon of AE tile fabrication process. Alkalinity enhanced tiles were made by dry mixing cement modifications and water for 4 min. Paste was cast into 3D-printed molds and cured for 24 h in ambient conditions for its initial cure. Tiles were then demolded and cured inside a humidity room (23 °C and >95% relative humidity) for an additional 27 days. Final conditioning for AE tiles varied based on intended experiment. Diffusion tiles were stored in plastic bags. Advection and aging tiles were stored in a tank with a bubbler. Tiles for biological experiments were conditioned in running seawater and live rocks for colonization. (b) 3D-printed female molds with two distinct surface topographies – flat and textured. (c) Tiles curing in >95% humidity room. (d) Top and side view of sample flat tile. (e) Top and side view of sample textured tile. (f) Tile dimensions for each topography type including designed measurements and actual measurements ± standard error (n = 4).

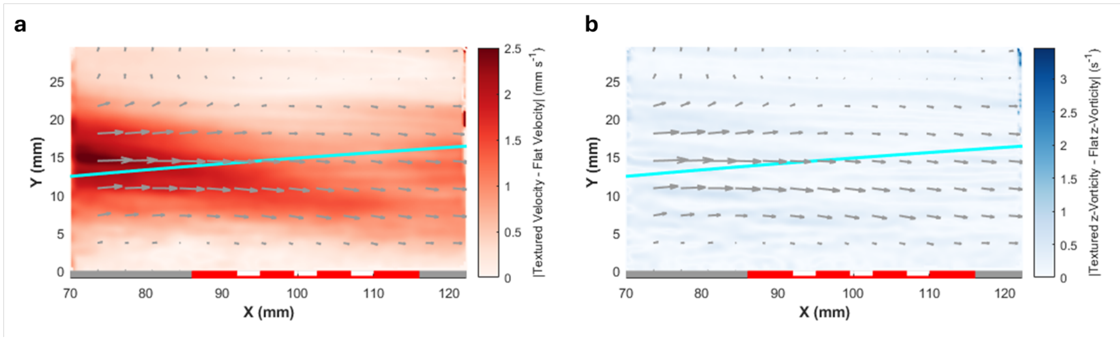

Figure 3: Topography hydrodynamic comparison. Difference in velocity (a) and vorticity (b) between flow over a flat tile and a textured tile. There are almost no differences (close to zero) in flow fields immediately above the divots (a, b). The noticeable changes in the center or bulk region (a) of ~0.2 cm s^{-1} are one order of magnitude smaller than the actual mean flows (1-2 cm s^{-1}) in the bulk (**Figure 1d**). The cyan line on both figures represents the boundary layer calculated from theory.

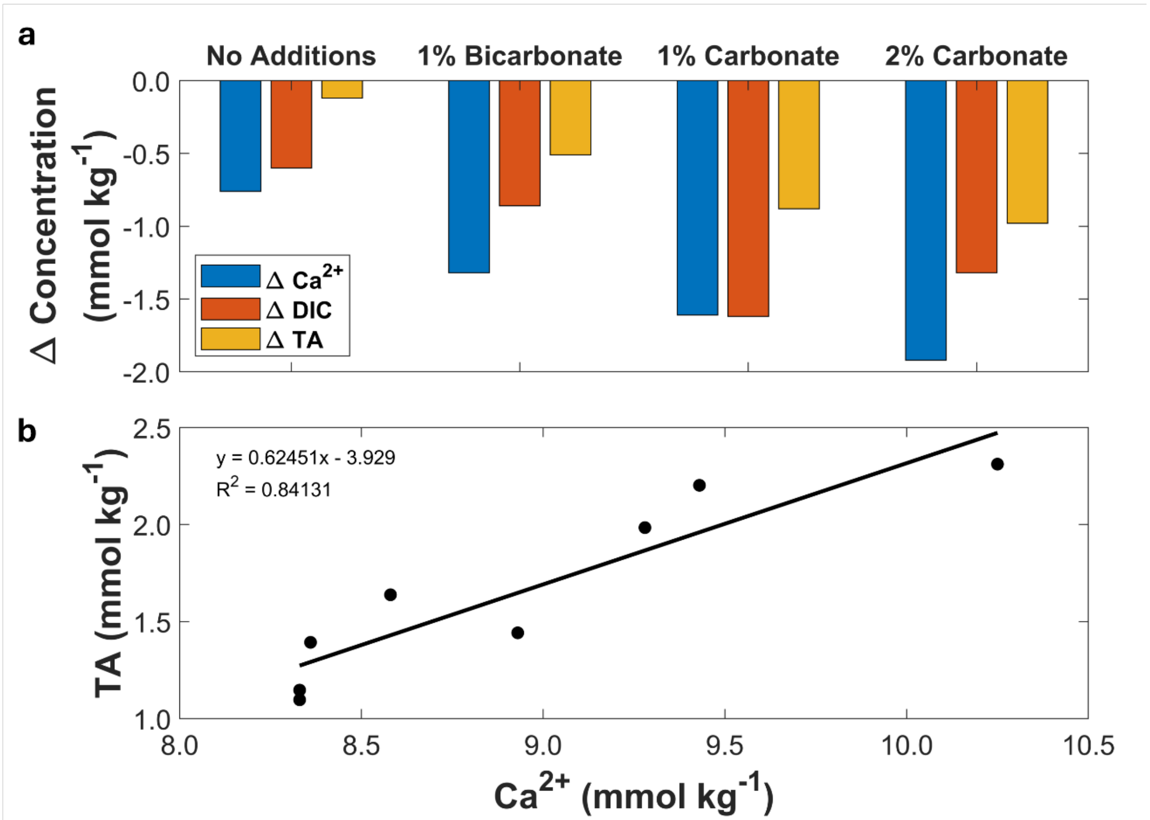

Figure 4: TA, DIC, and Ca measurements: (a) Change in concentrations of TA, DIC, and Ca^{2+} for the different tile chemistries. (b) TA-Ca^{2+} property-property plot showing the relationship between the draw down of Ca^{2+} and TA for the eight types of cement tiles relative to the initial chemistry of the seawater in the jars (right-most data point).

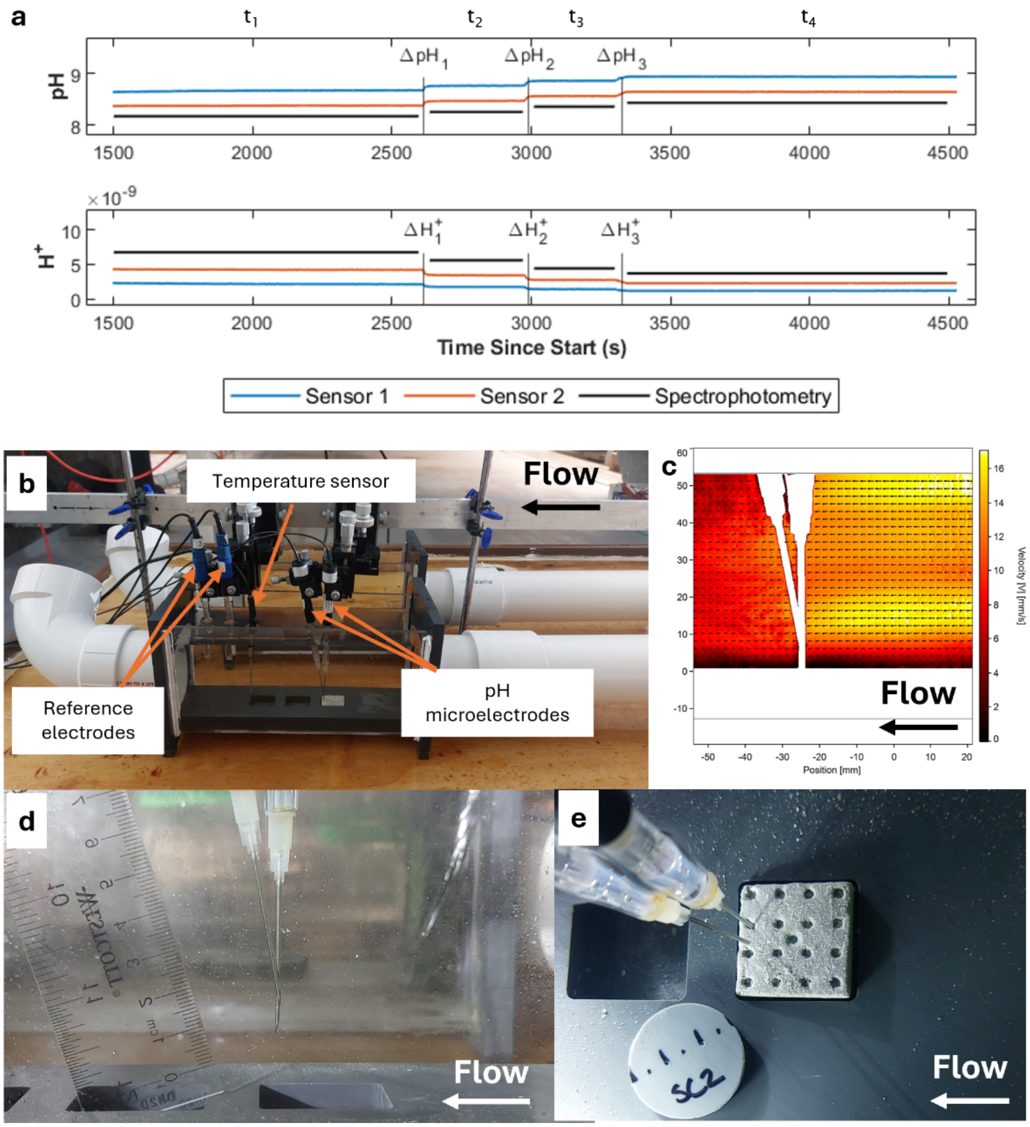

Figure 5: Chemical quantification of tile measurements. (a) Sensor accuracy was compared to measurements taken via pH spectrophotometry. Sensors measured 1L of saltwater on a magnetic stir plate to ensure a well-mixed environment. Aqueous bicarbonate was added at 4 time points (t_1-t_4) and the pH of the solution was measured by both microelectrodes and a sample was removed for measurement by titration. Numerical analysis is summarized in **Supplementary Table 9.** Change in values at these time points is consistent across sensors and spectrometry calculations indicating ΔpH and ΔH^+ analysis is reliable. (b) Standard placement of sensors for chemical measurements in flow through flumes. (c) Velocity field of flow around sensors in flow conditions. The flow upstream of the sensors is constant with no mixing. Downstream, minor fluctuations in flow occur due to the sensors. Microelectrodes are angled to sample upstream measurements. (d) Standard sensor position for chemical quantification of tiles in flow conditions for advective quantification and aging experiments. The open end of the needle microelectrodes points upstream. (e) Standard vertical sensor position for chemical quantification of textured tiles in flow conditions. One sensor is fully deployed into a divot, while the other sensor is positioned at a similar length along the tile at the surface.

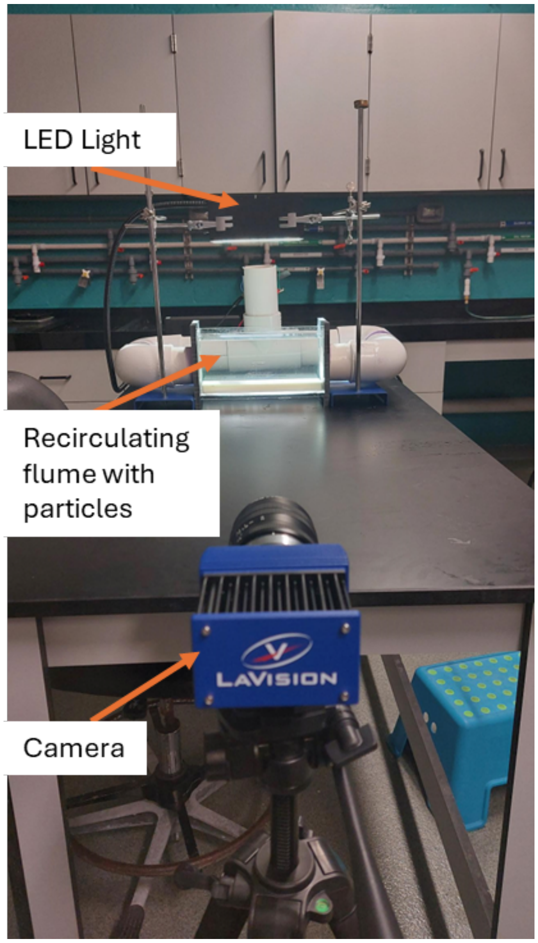

Figure 6: Particle image velocimetry (PIV) measurements. Two-dimensional particle image velocimetry (PIV) measurements were taken in a recirculating flume illuminated from above with an LED light source. The flume is seeded with neutrally buoyant particles, and flow is controlled via a propellor at the back of the flume. Videos are recorded with a camera and processed in DaVis software (not pictured).

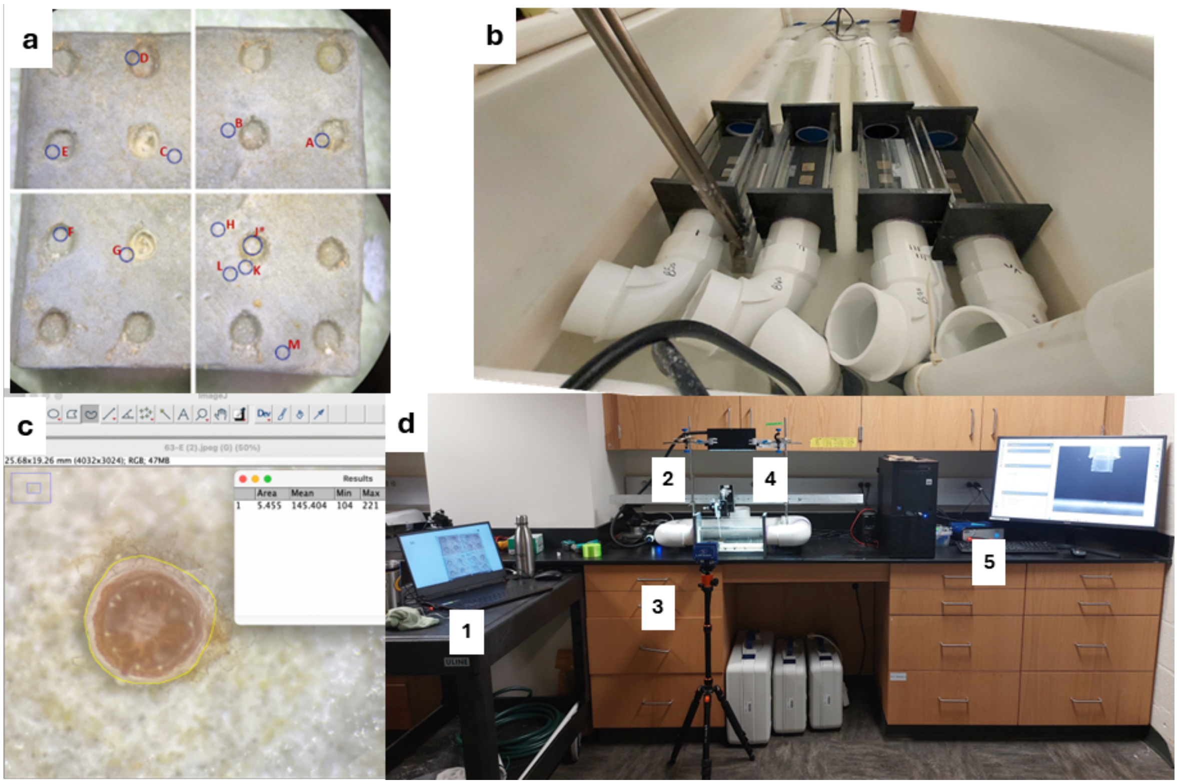

Figure 7: Coral rearing and measurements. (a) Sample coral map of *O. faveolata* settlement locations on a textured tile. (b) Four flow through flumes for *O. faveolata* rearing in a temperature-controlled water bath. (c) Sample areal measurement of *O. faveolata* in ImageJ software. Area is calculated using the freehand tool to draw around the perimeter of the coral (yellow). (d) Lab configuration of vertical growth measurements and steps for measurement. Coral on an experimental tile placed in the recirculating flume can be vertically measured by (1) locating the approximate settlement location of the settler map, (2) moving the calibration wand over the tile such that it matches the approximate location on the settlement map, (3) refining the measurement of the coral by focusing the camera on the coral, (4) finalizing the position of the calibration wand using the micromanipulator such that it is also in focus with the coral, and (5) capturing the image of the in-focus coral and calibration wand in DaVis software.

Table 1: Chemical characterization pairwise comparisons. Tukey HSD multiple comparisons for chemical characterization of alkalinity enhanced tiles. Statistics were run on ΔH^{+} values. Adjusted DF = 14403. All 28 unique combinations of chemistry and flow type are tested. PLC = no additions, SB1 = 1% bicarbonate additions, SC1 =1% carbonate additions, and SC2 = 2% carbonate additions. Significant p-values (<0.05) are highlighted in red.

Comparison		t	p
Advection x Advection	PLC x SB1	96.12	<0.0001
	PLC x SC1	157.91	<0.0001
	PLC x SC2	76.26	<0.0001
	SB1 x SC1	61.78	<0.0001
	SB1 x SC2	-19.86	<0.0001
	SC1 x SC2	-81.63	<0.0001
Diffusion x Diffusion	PLC x SB1	-36.08	<0.0001
	PLC x SC1	26.86	<0.0001
	PLC x SC2	101.22	<0.0001
	SB1 x SC1	62.99	<0.0001
	SB1 x SC2	137.38	<0.0001
	SC1 x SC2	74.43	<0.0001
Advection x Diffusion	PLC Advection x PLC Diffusion	169.44	<0.0001
	PLC Advection x SB1 Diffusion	133.49	<0.0001
	PLC Advection x SC1 Diffusion	196.42	<0.0001
	PLC Advection x SC2 Diffusion	270.65	<0.0001
	SB1 Advection x PLC Diffusion	73.30	<0.0001
	SB1 Advection x SB1 Diffusion	37.28	<0.0001
	SB1 Advection x SC1 Diffusion	100.22	<0.0001
	SB1 Advection x SC2 Diffusion	174.51	<0.0001
	SC1 Advection x PLC Diffusion	11.53	<0.0001
	SC1 Advection x SB1 Diffusion	-24.55	<0.0001
	SC1 Advection x SC1 Diffusion	38.40	<0.0001
	SC1 Advection x SC2 Diffusion	112.74	<0.0001
	SC2 Advection x PLC Diffusion	93.16	<0.0001
	SC2 Advection x SB1 Diffusion	57.16	<0.0001
	SC2 Advection x SC1 Diffusion	120.09	<0.0001
	SC2 Advection x SC2 Diffusion	194.37	<0.0001

Table 2: Aging regressions. Coefficients *a* and *b* for the fitted linear regressions "$\Delta H^+ = a$*Day+*b*" for each combination of chemistry and sensor position. PLC = no additions, SB1 = 1% bicarbonate additions, SC1 =1% carbonate additions, and SC2 = 2% carbonate additions. Significant p-values (<0.05) are highlighted in red.

		Fitted Function		R^2	DF	F	p
		a*	b*				
PLC	**Above**	2.63E-02	-1.02	0.12	(1,52)	7.17	0.01
	Surface	2.29E-02	-1.15	0.05	(1,52)	2.85	0.10
SB1	**Above**	1.50E-02	-1.64	0.03	(1,52)	1.71	0.20
	Surface	6.51E-02	-7.14	0.05	(1,52)	2.92	0.09
SC1	**Above**	2.64E-02	-1.78	0.06	(1,52)	3.08	0.09
	Surface	5.75E-02	-8.43	0.04	(1,52)	2.03	0.16
SC2	**Above**	2.42E-02	-1.62	0.08	(1,51)	4.73	0.03
	Surface	4.46E-02	-2.80	0.13	(1,51)	7.54	<0.01

*Divided by e-10

Table 3: Aging pairwise comparisons. Tukey HSD multiple comparisons for aging data. Statistics are run on *ΔH⁺* values. Adjusted DF for pairwise comparisons = 15836, DF for comparisons to 0 = 53. PLC = no additions, SB1 = 1% bicarbonate additions, SC1 =1% carbonate additions, and SC2 = 2% carbonate additions. "Above" refers to above the tile in the bulk flow, "Surface" refers to at the tile surface. Significant p-values (<0.05) are highlighted in red.

Comparison		t	p
Above x Above	PLC1 x SB1	1.11	0.95
	PLC1 x SC1	0.84	0.99
	PLC1 x SC2	0.74	1.00
	SB1 x SC1	-0.28	1.00
	SB1 x SC2	-0.37	1.00
	SC1 x SC2	-0.10	1.00
Surface x Surface	PLC1 x SB1	4.97	<0.0001
	PLC1 x SC1	6.67	<0.0001
	PLC1 x SC2	1.89	0.56
	SB1 x SC1	1.70	0.69
	SB1 x SC2	-3.08	0.05
	SC1 x SC2	-4.78	<0.0001
Above x Surface	PLC1 Above x PLC1 Surface	0.28	1.00
	PLC1 Above x SB1 Surface	5.25	<0.0001
	PLC1 Above x SC1 Surface	6.95	<0.0001
	PLC1 Above x SC2 Surface	2.16	0.38
	SB1 Above x SB1 Surface	4.14	0.00
	SB1 Above x PLC Surface	0.84	0.99
	SB1 Above x SC1 Surface	5.84	<0.0001
	SB1 Above x SC2 Surface	1.05	0.97
	SC1 Above x SC1 Surface	6.11	<0.0001
	SC1 Above x PLC1 Surface	0.56	1.00
	SC1 Above x SB1 Surface	-4.41	0.00
	SC1 Above x SC2 Surface	1.33	0.89
	SC2 Above x SC2 Surface	1.43	0.84
	SC2 Above x PLC1 Surface	0.46	1.00
	SC2 Above x SB1 Surface	-4.51	0.00
	SC2 Above x SC1 Surface	-6.21	<0.0001
Compare to estimated mean = 0	PLC Above x 0	-0.43	0.67
	SB1 Above x 0	-3.92	<0.001
	SC1 Above x 0	-2.30	0.03
	SC2 Above x 0	-2.75	<0.01
	PLC Surface x 0	-1.06	0.29
	SB1 Surface x 0	-5.09	<0.001
	SC1 Surface x 0	-6.40	<0.001
	SC2 Surface x 0	-2.21	0.03

Table 4: Chemistry X Topography pairwise comparisons. Tukey HSD multiple comparisons for chemistry x topography data. Statistics are run on ΔH^+ values. Adjusted DF for pairwise comparisons = 43320. All 28 unique combinations of chemistry and sensor position are tested. PLC = no additions, SB1 = 1% bicarbonate additions, SC1 =1% carbonate additions, and SC2 = 2% carbonate additions. "Surface" refers to the surface of the tile, and "Divot" refers to at the bottom of the divot. Significant p-values (<0.05) are highlighted in red.

Comparison		t	p
Surface x Surface	PLC1 x SB1	51.78	<0.0001
	PLC1 x SC1	72.70	<0.0001
	PLC1 x SC2	-137.10	<0.0001
	SB1 x SC1	21.14	<0.0001
	SB1 x SC2	-188.60	<0.0001
	SC1 x SC2	-208.80	<0.0001
Divot x Divot	PLC1 x SB1	6.25	<0.0001
	PLC1 x SC1	29.23	<0.0001
	PLC1 x SC2	11.64	<0.0001
	SB1 x SC1	22.98	<0.0001
	SB1 x SC2	5.38	<0.0001
	SC1 x SC2	-17.61	<0.0001
Surface x Divot	PLC1 Surface x PLC1 Divot	-635.60	<0.0001
	PLC1 Surface x SB1 Divot	-628.40	<0.0001
	PLC1 Surface x SC1 Divot	-602.30	<0.0001
	PLC1 Surface x SC2 Divot	-622.50	<0.0001
	SB1 Surface x PLC1 Divot	686.40	<0.0001
	SB1 Surface x SB1 Divot	-679.10	<0.0001
	SB1 Surface x SC1 Divot	-652.90	<0.0001
	SB1 Surface x SC2 Divot	-673.20	<0.0001
	SC1 Surface x PLC Divot	704.27	<0.0001
	SC1 Surface x SB1 Divot	696.98	<0.0001
	SC1 Surface x SC1 Divot	-670.80	<0.0001
	SC1 Surface x SC2 Divot	-691.10	<0.0001
	SC2 Surface x PLC Divot	497.05	<0.0001
	SC2 Surface x SB1 Divot	490.05	<0.0001
	SC2 Surface x SC1 Divot	464.74	<0.0001
	SC2 Surface x SC2 Divot	-484.30	<0.0001

Table 5: Settlement and survivorship pairwise comparisons. Multiple comparisons for initial number of settlers with respect to chemistry and topography, total survivorship with respect to chemistry and topography, and for location survivorship with respect to chemistry and settlement location. Significant p-values (<0.05) are highlighted in red.

Response Variable	Factors	Posthoc Test	Comparison	Test Statistic	p
Initial Number of Settlers	Chemistry X Topography	Steel-Dwass All Pairs	No addition, Flat - 1% Carbonate, Flat	1.77	0.39
			No addition, Flat - 2% Carbonate, Flat	0.89	0.90
			No addition, Flat - No addition, Textured	1.75	0.41
			No addition, Flat - 1% Carbonate, Textured	1.75	0.41
			1% Carbonate, Flat - 2% Carbonate, Flat	-0.68	0.96
			1% Carbonate, Flat - No addition, Textured	1.77	0.39
			1% Carbonate, Flat - 1% Carbonate, Textured	1.57	0.51
			2% Carbonate, Flat - No addition, Textured	1.77	0.39
			2% Carbonate, Flat - 1% Carbonate, Textured	-1.57	0.51
			No addition, Textured - 1% Carbonate, Textured	1.55	0.53
arcsin(sqrt(Total Survivorship))	Chemistry X Topography	Tukey's HSD	No addition, Flat - 1% Carbonate, Flat	-1.79	0.43
			No addition, Flat - 2% Carbonate, Flat	-2.57	0.15
			No addition, Flat - No addition, Textured	0.31	1.00
			No addition, Flat - 1% Carbonate, Textured	0.83	0.92
			1% Carbonate, Flat - 2% Carbonate, Flat	-0.79	0.93
			1% Carbonate, Flat - No addition, Textured	2.10	0.29
			1% Carbonate, Flat - 1% Carbonate, Textured	2.62	0.14
			2% Carbonate, Flat - No addition, Textured	2.89	0.09
			2% Carbonate, Flat - 1% Carbonate, Textured	-3.40	0.04
			No addition, Textured - 1% Carbonate, Textured	-0.51	0.98
arcsin(sqrt(Location Survivorship))	Chemistry X Location	Tukey's HSD	No addition, Surface - 1% Carbonate, Surface	-0.89	0.90
			No addition, Surface - 2% Carbonate, Surface	-2.23	0.22
			No addition, Surface - No addition, Divot	-0.88	0.90
			No addition, Surface - 1% Carbonate, Divot	1.38	0.65
			1% Carbonate, Surface - 2% Carbonate, Surface	-1.50	0.58
			1% Carbonate, Surface - No addition, Divot	-1.60	0.52
			1% Carbonate, Surface - 1% Carbonate, Divot	-2.10	0.27
			2% Carbonate, Surface - No addition, Divot	-2.69	0.10
			2% Carbonate, Surface - 1% Carbonate, Divot	-3.12	0.04
			No addition, Textured - 1% Carbonate, Textured	0.43	0.99

Table 6: Water chemistry results from TA, DIC, and Ca measurements. PLC = no additions, SB1 = 1% bicarbonate additions, SC1 =1% carbonate additions, and SC2 = 2% carbonate additions.

Day	Tile Type	pH	Salinity	DIC	TA	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}	Sr^{2+}
			(mmol kg^{-1})							
0	Seawater	7.979	34.6	2.078	2.311	410.0	8.49	10.25	41.8	0.096
11	PLC, flat	8.348	34.6	1.361	lost	419.4	8.95	9.56	42.5	0.094
11	PLC, textured	8.568	34.6	1.593	2.202	411.0	8.85	9.43	41.9	0.087
11	SB1, flat	8.490	34.6	1.178	1.638	405.4	8.70	8.58	41.1	0.075
11	SB1, textured	8.728	34.6	1.257	1.984	418.3	9.16	9.28	43.2	0.081
11	SC1, flat	8.562	34.6	0.927	1.442	420.7	9.34	8.93	43.5	0.072
11	SC1, textured	8.865	34.6	lost	1.393	420.8	9.26	8.36	44.0	0.065
11	SC2, flat	8.822	34.6	0.577	1.097	425.5	9.44	8.33	45.5	0.068
11	SC2, textured	8.585	34.6	0.941	1.147	414.5	9.00	8.33	43.9	0.067

Table 7: Results of Anderson-Darling Tests for Normality. Anderson-Darling tests for normality assume data is taken from a normal distribution ($p<0.05$ indicates data is not normally distributed). Chemistry has three levels; no additions (PLC), 1% carbonate additions (SC1), or 2% carbonate additions (SC2): Topography has two levels; flat or textured tile: Chemistry X Topography has five levels: PLC-Flat, PLC-Textured, SC1-Flat, SC1-Textured, SC2-Flat; and Location has three levels: surface across all tiles (regardless of topography), surface of textured tiles, divots. Independent variables tested include the total number of settlers per tile, % settlers on surface, % settlers in divots, % settlement aggregates % settlers on surface and % settlers in divots, total survivorship regardless of settlement location (%), surface survivorship (%), divot survivorship (%), location survivorship which aggregates both surface and divot survivorship (%), Δ skeletal height (mm), Δ surface area (mm^2), and Δ volume (mm^3). All percentage data has undergone an arcsin transformation. Significant p-values (<0.05) are highlighted in red.

Factor	Level	Stat	Variable										
			Settlement Preference				Survivorship				Growth		
			Total Number of Settlers	arcsin(sqrt(% Settlers on Surface))	arcsin(sqrt(% Settlers in Divots))	arcsin(sqrt(% Settlement))	arcsin(sqrt(Total Survivorship))	arcsin(sqrt(Surface Survivorship))	arcsin(sqrt(Divot Survivorship))	arcsin(sqrt(Location Survivorship))	Δ Skeletal Height (mm)	Δ Surface Area (mm^2)	Δ Volume (mm^3)
Chemistry	PLC	n	6	6	3	9	6	6	3	9	4	4	4
		A^2	0.33	0.69	0.36	0.42	0.23	0.32	0.47	0.37	0.21	0.54	0.24
		p	0.42	0.03	0.26	0.28	0.74	0.44	0.04	0.39	0.79	0.06	0.70
	SC1	n	6	6	3	9	6	6	3	9	5	5	5
		A^2	0.56	0.54	0.20	0.45	0.16	0.36	0.49	0.42	0.21	0.42	0.43
		p	0.07	0.08	0.84	0.24	0.95	0.37	<0.0001	0.27	0.82	0.22	0.20
	SC2	n	3				3				3	3	3
		A^2	0.49		*NA*		0.19		*NA*		0.19	0.33	0.23
		p	<0.0001				0.95				0.98	0.32	0.66
Topography	Flat	n	9				9				8	8	8
		A^2	0.27		*NA*		0.37		*NA*		0.55	0.40	0.42
		p	0.65				0.36				0.11	0.28	0.25
	Textured	n	6	6	6	12	6	6	6	12	4	4	4
		A^2	0.32	0.36	0.36	0.41	0.45	0.30	0.82	0.37	0.36	0.36	0.28
		p	0.45	0.37	0.36	0.31	0.19	0.50	0.02	0.06	0.28	0.27	0.54
Chemistry x Topography	PLC, Flat	n	3				3				2	2	2
		A^2	0.23		*NA*		0.37		*NA*		0.25	0.25	0.25
		p	0.66				0.23				<0.0001	0.38	<0.0001
	PLC, Textured	n	3	3	3	6	3	3	3	6	2	2	2
		A^2	0.37	0.36	0.36	0.18	0.45	0.19	0.47	0.37	0.25	0.25	0.25
		p	0.22	0.25	0.25	0.90	0.06	0.98	0.04	0.32	<0.0001	0.34	0.38
	SC1, Flat	n	3				3				3	3	3
		A^2	0.49		*NA*		0.28		*NA*		0.33	0.34	0.34
		p	<0.0001				0.46				0.31	0.29	0.31
	SC1, Textured	n	3	3	3	6	3	3	3	6	2	2	2
		A^2	0.19	0.20	0.20	0.26	0.21	0.28	0.49	0.52	0.25	0.25	0.25
		p	1	0.83	0.83	0.64	0.72	0.45	<0.0001	0.11	0.37	0.37	0.34
	SC2, Flat	n	3				3				3	3	3
		A^2	0.49		*NA*		0.19		*NA*		0.19	0.33	0.23
		p	<0.0001				0.95				0.98	0.31	0.66
Location	Surface (all)	n				15				15			
		A^2		*NA*		2.05		*NA*		0.56			
		p				<0.0001				0.12			
	Surface (Textured only)	n				6				6			
		A^2		*NA*		0.36		*NA*		0.30			
		p				0.37				0.52			
	Divot (Textured only)	n				6				6			
		A^2		*NA*		0.36		*NA*		0.82			
		p				0.37				0.01			

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Table 8: Results of Levene Tests for Equal Variance. Levene's test for equal variance assume data has equal variance across groups ($p<0.05$ indicated unequal variance between groups). Chemistry compares across three groups; no additions (PLC), 1% carbonate additions (SC1), or 2% carbonate additions (SC2): Topography compares across two groups; flat or textured tile: Chemistry X Topography compares across five groups: PLC-Flat, PLC-Textured, SC1-Flat, SC1-Textured, SC2-Flat; Settlement location has two groups: surface or divot, and is featured twice to indicate comparisons within textured tiles (notated with an asterisk) and across flat and textured tiles (no asterisk); and Chemistry X Settlement Location has five groups: PLC-Surface, PLC-Divot, SC1-Surface, SC1-Divot, SC2-Surface. Independent variables tested include the total number of settlers per tile, % settlers on surface, % settlers in divots, % settlement aggregates % settlers on surface and % settlers in divots, total survivorship regardless of settlement location (%), surface survivorship (%), divot survivorship (%), location survivorship which aggregates both surface and divot survivorship (%), Δ skeletal height (mm), Δ surface area (mm^2), and Δ volume (mm^3). All percentage data has undergone an arcsin transformation. Significant p-values (<0.05) are highlighted in red.

Factor	Stat	Variable										
		Settlement Preference				Survivorship				Growth		
		Total Number of Settlers	arcsin(sqrt(% Settlers on Surface))	arcsin(sqrt(% Settlers in Divots))	arcsin(sqrt(% Settlers))*	arcsin(sqrt(Total Survivorship))	arcsin(sqrt(Surface Survivorship))	arcsin(sqrt(Divot Survivorship))	arcsin(sqrt(Location Survivorship))	Δ Skeletal Height (mm)	Δ Surface Area (mm^2)	Δ Volume (mm^3)
Chemistry	DF(x,y)	(2,12)	(2,12)	(1,4)	(2,18)	(2,12)	(2,12)	(1,4)	(2,18)	(2,9)	(2,9)	(2,9)
	F	8.17	20.45	0.65	4.84	0.86	0.84	0.07	1.28	0.25	0.32	0.23
	p	<0.01	<0.001	0.47	0.02	0.45	0.46	0.81	0.30	0.78	0.74	0.80
Topography	DF(x,y)	(1,13)				(1,13)	(1,13)		(1,19)	(1,10)	(1,10)	(1,10)
	F	1.80		*NA*		1.47	0.29	*NA*	0.11	2.57	4.31	2.63
	p	0.20				0.25	0.60		0.74	0.14	0.06	0.14
Chemistry x Topography	DF(x,y)	(4,10)		(1,4)		(4,10)	(4,10)	(1,4)	(4,16)	(4,7)	(4,7)	(4,7)
	F	2.91	*NA*	0.65	*NA*	1.76	0.78	0.07	0.71	3.36	3.64	2.08
	p	0.08		0.47		0.21	0.56	0.81	0.59	0.08	0.07	0.19
Settlement Location*	DF(x,y)				(1,10)				(1,10)			
	F		*NA*		0.00		*NA*		1.74			
	p				1.00				0.22			
Settlement Location	DF(x,y)				(1,19)				(1,19)			
	F		*NA*		22.98		*NA*		0.89			
	p				<0.001				0.36			
Chemistry X Settlement Location	DF(x,y)				(4,16)				(4,16)			
	F		*NA*		16.17		*NA*		0.66			
	p				<0.0001				0.63			

Table 9: Sensor Verification. pH sensors were verified by comparing their recorded values with spectrophotometry analysis of pH (**Supplementary Figure S5a**). Known amounts of sodium bicarbonate were added to 1L of water, and sensors were allowed to record. Data is presented as mean ± standard deviation for pH and H^+ calculations. While raw pH and H^+ measurements do not align with spectrophotometry measurements, accounting for error, ΔpH and ΔH^+ calculations on sensors capture the same changes as spectrophotometry, indicating high reliability of sensor measurements.

	Sensor 1		**Sensor 2**		**Spectrophotometry**	
	pH	**H^+**	**pH**	**H^+**	**pH**	**H^+**
t_1	8.664 ± 0.010	2.17E-9 ± 4.62E-11	8.375 ± 0.003	4.22E-9 ± 3.01E-11	8.170	6.76E-9
t_2	8.767 ± 0.017	1.71E-9 ± 6.17E-11	8.471 ± 0.018	3.68E-9 ± 1.26E-10	8.252	5.60E-9
t_3	8.859 ± 0.001	1.38E-9 ± 3.03E-12	8.563 ± 0.001	2.73E-9 ± 4.05E-12	8.356	4.41E-9
t_4	8.939 ± 0.002	1.15E-9 ± 5.59E-12	8.645 ± 0.002	2.28E-9 ± 8.33E-12	8.433	3.69E-9
ΔpH_1	0.103 ± 0.027		0.096 ± 0.021		0.082	
ΔpH_2	0.092 ± 0.018		0.092 ± 0.019		0.104	
ΔpH_3	0.080 ± 0.003		0.082 ± 0.003		0.077	
ΔH^+_1	-4.60E-10 ± 1.13E-10		-5.40E-10 ± 1.56E-10		-1.16E-9	
ΔH^+_2	-3.30E-10 ± 6.47E-11		-9.50E-10 ± 1.30E-10		-1.19E-9	
ΔH^+_3	-2.30E-10 ± 8.62E-12		-4.50E-9 ± 1.24E-11		-7.20E-9	