Electronic Supplemental Material for "*Common Caribbean corals exhibit highly variable responses to future acidification and warming*"

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Supplemental Methods:

(a) Coral collection

In June 2015, 6 colonies each of 4 reef-building coral species (*Siderastrea siderea, Pseudodiploria strigosa, Porites astreoides,* and *Undaria tenuifolia*; figure S1) were collected from an inshore reef (Port Honduras Marine Reserve; 16°11'23.5314"N, 88°34'21.9360"W) and 6 colonies of each of the 4 coral species were collected from an offshore reef (Sapodilla Cayes Marine Reserve; 16°07'00.0114"N, 88°15'41.1834"W) along the Belize Mesoamerican Barrier Reef System (MBRS) at a depth of 3 to 5 m. A total of 48 coral colonies were collected from both reef environments (2 reef environments x 4 species x 6 colonies). The inshore reef is 9 km from the mainland of Belize, while the offshore reef is approximately 37 km from the mainland.

(b) Experimental design and setup

Corals were transported to Northeastern University's natural flow-through seawater system located at the Marine Science Centre, where corals were sectioned with a seawater-cooled tile-cutting saw. Each sectioned coral fragment (approximate surface area: 5 cm x 3 cm = 15 cm^2; approximate thickness: 2 cm) was mounted on to the outer surface of a 47 mm polystyrene petri dish (EMD Millipore; Billerica, Massachusetts, USA) using Loctite® cyanoacrylate adhesive (Düsseldorf, Germany). All 384 coral fragments (i.e., 48 colonies x 8 fragments) were placed into 1 of 8 treatments (4 fragments per species per tank; 16 fragments per tanks; 384 fragments in total; figure S2) filled with 5 µm-filtered seawater obtained from Massachusetts Bay off the coast of Boston, Massachusetts (see table S1 for *in situ* water chemistry data from Belize) [1, 2]. Corals were maintained in natural seawater at a salinity (±SD) of 30.7 (±0.8) and temperature (±SD) of 28.2°C (±0.5) for a recovery period of 23 days. After recovery, temperature and pCO$_2$ were adjusted every other day over a 20-day interval until target experimental conditions were approximately achieved for each treatment (temperature: 28 and 31°C; pCO$_2$: 280, 400, 700, 2800 µatm). Seawater temperatures in experimental tanks was incrementally increased by 0.4°C every 3 days and experimental pCO$_2$ was adjusted by –12 µatm (pre-industrial), 0 µatm (current-day), +30 µatm (end-of-century), and +240 µatm (extreme) during the 20-day adjustment interval before starting the 30-day acclimation period. Four pCO$_2$ treatments corresponding to pre-industrial (311/288 µatm), current-day (pCO$_2$ control; 405/447 µatm), end-of-century (701/673 µatm), and an extreme (3309/3285 µatm) pCO$_2$ were maintained at two temperatures corresponding to the corals' approximate present day mean annual temperature (28°C; determined by over 10 years of *in situ* records) [3-5] and projected end-of-century annual mean temperature (31°C) [6].

Experimental 42 L acrylic tanks were illuminated by full spectrum LED lights (Euphotica; 120W, 20000K) on a 10:14 h light:dark cycle with photosynthetically active radiation (PAR) of ca. 300 µmol photons m^{-2} s^{-1} to simulate natural light cycles occurring within the corals' native habitat [7]. PAR was regularly measured within each tank using a LI-COR LI-1500 data logger affixed with a LI-COR LI-192 2π underwater quantum sensor (LI-COR; Lincoln, Nebraska, USA;

figure S3). Experimental tanks were covered with an acrylic lid and wrapped in cellophane plastic to facilitate equilibrium between the gas mixtures and the experimental seawaters and to minimize evaporative water loss. Circulation and turbulence in the experimental tanks were maintained with a Maxi-Jet® 400 L h^{-1} powerhead (Marineland; Blacksburg, Virginia, USA), which have been used in previous common garden experiments on corals from Belize [7, 8]. Freshly filtered natural seawater was added via the flow-through system so that the water in each tank was replenished *ca.* 1.3 times per day.

Experimental pCO_2 gas mixtures were measured using Qubit S151 (range 0-2000 µatm; accuracy ± 1 µatm) and S153 (range 0-10%; accuracy ± 0.3%) infrared pCO_2 analyzers (Qubit Systems; Kingston, Ontario, Canada) calibrated with certified air-CO_2 gas standards. High-precision digital solenoid-valve mass flow controllers (*Aalborg* Instruments and Controls; Orangeburg, NY, USA) were used to bubble air alone (401; 447 µatm), or in combination with CO_2-free air (311; 288 µatm) or CO_2 gas (701; 673; 3309; 3285 µatm) with compressed air to achieve gas mixtures of the desired pCO_2, and bubbled into each tank and sump via flexible air bubblers (table 2; figure S4). Because temperature affects the solubility of CO_2 in seawater, the two temperature treatments averaged different carbonate parameters for each of the pCO_2 treatments, despite being sparged with the same gas mixture ratios (figure S4). These eight pCO_2-temperature (±SE) combinations were replicated three-fold (24 tanks total) and yielded the following treatment conditions (±SD): 311 (±96), 405 (±91), 701 (±94), 3309 (±414) µatm pCO_2 at 28°C (±0.4); and 288 (±65), 447 (±152), 673 (±104), 3285 (±484) µatm pCO_2 at 31.0°C (±0.4). The temperature of both the 28 and 31°C treatments were maintained using 50W glass aquarium heaters within each tank and 75W glass aquarium heaters (EHEIM; Deizisau, Germany) in each sump. Temperature, salinity, and pH were measured every other day and water samples were taken using 250 mL ground-glass-stoppered borosilicate glass bottles around 13:00 Eastern Time every 10 days throughout the 93-day experimental period (9 September – 17 December 2015). Total alkalinity was determined by closed-cell potentiometric Gran titration and DIC was determined by coulometry (UIC 5400), with both methods calibrated with certified Dickson Laboratory standards for seawater CO_2 measurements (Scripps Institution of Oceanography; San Diego, California, USA). Measured temperature, salinity, TA, and DIC were used to calculate carbonate parameters using CO_2SYS [9] with Roy et al. (1993) carbonic acid constants K_1 and K_2 [10], the Mucci (1983) value for the stoichiometric aragonite solubility product [11], and an atmospheric pressure of 1.015 atm (electronic supplementary material; figure S4; tables S2, S3). Moderate deviations between calculated and targeted parameters throughout the duration of the experiment resulted largely from biological activity within the aquaria and from minor seasonal changes in source water chemistry. Temperature was measured using a high precision partial-immersion glass thermometer (precision ±0.3%; accuracy ±0.4%). Salinity (±SD) was measured using a YSI 3200 (Yellow Springs, Ohio, USA) conductivity meter with a 10.0 cm^{-1} cell and maintained at 31.7 (±0.2), with slight natural seasonal variation as expected in Massachusetts Bay waters. An AccuFet™ Solid-State pH probe (Fisher Scientific™; Waltham, Massachusetts, USA) calibrated with 7.00 and 10.01 NBS buffers maintained at experimental temperatures was used to measure pH in each tank (table S2; figure S4). Coral fragments within each tank were fed every other day with a mixture of *ca.* 6 g frozen adult *Artemia* sp. and 250 mL concentrated newly hatched live *Artemia* sp. (500 mL^{-1}) to satisfy any heterotrophic feeding by each species [12, 13].

(c) Buoyant weight quantification

Coral fragments were suspended in a 38 L aquarium 4 cm below the surface in seawater (temperature, 28.2°C; salinity, 32.4) using an aluminum wire hanging from a Nimbus NBL 423e Precision Balance (±0.0002 precision, ±0.002 accuracy; AE Adam®; Oxford, Connecticut, USA). A standard of a known mass was weighed three times before weighing corals in each tank to monitor any deviations in the balance over the course of the experiment. Each coral fragment was weighed three times, averaged, and normalized to surface area. Surface area was quantified in triplicate from photos of each nubbin taken at corresponding intervals using imaging software (IMAGE J).

A subsample of fragments from each coral species was selected for constructing the linear regression between buoyant weight and dry weight to validate the relationship between the two measurements. Buoyant weight and dry weight of the fragments are highly correlated ($R^2_{S.\ siderea} = 0.970$, $p < 0.001$; $R^2_{P.\ strigosa} = 0.900$, $p < 0.001$; $R^2_{P.\ astreoides} = 0.980$, $p < 0.001$; $R^2_{U.\ tenuifolia} = 0.983$, $p < 0.001$), therefore the change in growth in buoyant weight should be equivalent to the corresponding dry weight change (figure S5).

S. siderea: Dry weight (mg) = 1.9 * BW + 3.47, $R^2 = 0.970$
P. strigosa: Dry weight (mg) = 1.78 * BW + 5.47, $R^2 = 0.900$
P. astreoides: Dry weight (mg) = 1.93 * BW + 4.51, $R^2 = 0.980$
U. tenuifolia: Dry weight (mg) = 1.66 * BW + 5.04, $R^2 = 0.983$

(d) Linear Extension

A calcein horizon was line emplaced into coral skeletons at the beginning of the experiment to establish a marker from which linear extension throughout the experiment could be measured [14]. Each experimental tank was dosed with 213.4 g of a 1% calcein solution for 5 days. During this period, the light cycle was increased to 14 h light in all tanks to ensure sufficient uptake of fluorescent marker into skeletons. At the completion of the experiment, tissue was removed from all coral fragments using a precision seawater sprayer (PointZero; Sunrise, Florida, USA). Sections 5mm thick were cut from the middle of each fragment using a DB-100 ReefKeeper™ diamond band saw (Inland; Madison Heights, Michigan, USA). The full thin sections were imaged under a stereo microscope outfitted with a blue fluorescent adapter with excitation 440–460nm (NIGHTSEA™; Lexington, Massachusetts, USA). Linear extension was measured as the total area of new growth above the calcein line (figure S7) measured using imaging software (IMAGE J) divided by the measured length of the coral's growth axis. Extension was then divided by the number of months in the experimental treatments resulting in linear extension per month (mm $month^{-1}$).

(e) Estimation of gross calcification rates

Gross calcification rates were estimated by subtracting the corals' calculated gross dissolution rates from their net calcification rates at the aragonite saturation states of each treatment. Gross dissolution was calculated using gross dissolution regression equations derived in Ries et al. [15] for two coral species. The equation for *S. siderea* from Ries et al. was used for *S. siderea*, *P. strigosa*, and *P. astreoides* from the current experiment, and the *O. arbuscula* equation was used with *U. tenuifolia* fragments [15] (figure S8).

S. siderea: $y = 0.055 - 0.638 * e^{(-6.187 * \Omega_A + 2.039 * \Omega_A)}$

O. arbuscula: $y = 0.073 - 0.638 * e^{(-5.632 * \Omega_A + 2.039 * \Omega_A)}$

(f) Survival quantification and analysis

Coral fragments were assessed for mortality every 30 days and considered dead when no living tissue remained. Impacts of pCO_2 and temperature on survival rates were assessed using a Kaplan-Meier estimate of survival (*survfit*, *survival*, 2.39-5) [16]. Cox proportional hazard models, with colony nested within tank as a random effect, were performed using *coxme* (2.2-5) [17].

(g) Further explanation of statistical analyses

Linear mixed effects models were fit to the calcification and linear extension data. Models were run to include species, pCO_2 (factor), and temperature (factor), as fixed effects with colony (genotype) and tank as random effects:

lmer(rate ~ species * (pCO_2 + temperature) + (1 + species | tank) + (1 + (pCO_2 + temperature) | colony)

This model was selected using AIC and log likelihood tests to determine the best fit for the data. A parametric bootstrap of the data was run 1500 times for each model, resulting in the modelled mean and 95% confidence intervals. Colonies were pooled by natal reef environment in all analyses because this was not a significant predictor of any measured parameter. All statistical analyses were performed using R 3.3.2 for OS X [18].

Supplemental Results:

(a) Coral survivorship

Siderastrea siderea maintained nearly 100% survival across treatments, resulting in no significant effect of temperature ($p = 0.23$), pCO_2 ($p = 0.60$), or their interaction ($p = 1.0$) on survival (figure S6a). Survival of *P. strigosa*, *P. astreoides*, and *U. tenuifolia* reared at 31°C was significantly reduced compared to conspecifics reared at 28°C ($p < 0.01$, $p < 0.01$, $p < 0.01$, respectively; figure 3b-d). No *U. tenuifolia* fragments under extreme pCO_2 conditions at 31°C survived the acclimation period, indicating that this species is extremely sensitive to these conditions. Increasing pCO_2 had no effect on survival of *P. astreoides* or *U. tenuifolia* ($p = 0.09$ and $p = 0.22$, respectively), while increasing pCO_2 significantly increased survivorship of *P. strigosa* ($p < 0.01$), a trend driven by relatively low survival at present-day pCO_2. Finally, the interaction between pCO_2 and temperature had no significant effect on survivorship of *P. strigosa*, *P. astreoides*, or *U. tenuifolia* ($p < 0.08$, $p < 0.25$, $p < 0.21$, respectively; figure S6b-d; tables S10, S11, S12).

(b) Effects of exposure duration on calcification rate

Differences in calcification rates for the four species were also examined across three 30-day observation intervals (T0-T30, T31-60, and T61-T90) to assess the impact of duration of exposure to treatment conditions on coral calcification rates. Although responses are complex, some general patterns emerged. *Siderastrea siderea* exhibited a slight increase in calcification rates from the first (T0-T30) to second (T31-T60) intervals in most treatments, followed by a decline from the second to third (T61-T90) interval. In addition, calcification rates for coral reared at 28°C and 31°C under extreme pCO_2 are lower at each interval when compared with the lower pCO_2 treatments.

Calcification rates of *P. strigosa* were generally higher 28°C than at 31°C at every 30-day interval, regardless of pCO_2 treatment. With the exception of the corals reared under current-day pCO_2 at 28°C, calcification rates exhibited a declining trend at every 30-day interval throughout the experiment.

Porites astreoides calcification rates demonstrated a declining trend across observational intervals within most tempearature-pCO_2 treatment combinations, resulting in net dissolution at the final interval. The exception was for corals reared under extreme pCO_2 that never demonstrated net calcification at any of the three intervals at both temperatures.

Calcification rates of *U. tenuifolia* exhibited a decreasing trend at every interval across all pCO_2 and temperature treatment combinations. Missing data from the 31°C treatment in both the current-day and extreme pCO_2 treatments represents the low survival in these treatments. In addition, calcification rate trends within pCO_2 treatments were similar at both 28°C and 31°C (figure S12).

Supplemental Discussion:

(a) Corals' natal reef environment does not influence resilience to pCO_2 or thermal stress

Rates of calcification, linear extension, and survival were not significantly impacted by natal reef environment (i.e., inshore vs. offshore) of the four coral species investigated here (figures S10, S11, and tables S12, S13, S14). This result is consistent with previous laboratory experiments on some of the same and other species of zooxanthellate corals, which found no difference in responses to thermal and pCO_2 stress due to natal reef environment [7, 8], but inconsistent with historical growth records of *S. siderea* obtained from century-scale coral cores that showed that the extension rate of forereef colonies has declined much faster than that of backreef and nearshore colonies [19]. However, it is possible that natal-reef-environment differences in resilience to thermal stress may emerge with prolonged exposure to acidification and warming stress, as well as with larger sample sizes.

Supplemental tables and figures:

Reef environment	T (°C)	pCO_2 (μatm)	pH	TA (μM)	DIC (μM)	Ω_A	Salinity
Inshore	26.7	346.7	8.05	2495.9	2112	4.56	32.8
Inshore	26.7	326	8.04	2485.9	2090	4.68	32.7
Offshore	27.5	302.5	8.06	2572.8	2124	5.2	34.8
Offshore	27.5	298.1	8.06	2579.3	2126	5.25	34.8
Offshore	27.5	287.5	8.06	2583.8	2120	5.37	34.8

Table S1. Measured *in situ* carbonate parameters taken in December 2016 from an inshore and offshore location in southern Belize near coral sampling sites demonstrating similarity to experimental seawater (see table 1).

		MEASURED PARAMETERS							
***p*$CO_{2\,(gas\text{-}e)}$**	(µatm-v)	311	405	701	3309	288	447	673	3285
Sal	(psu)	31.72	31.77	31.69	31.77	31.74	31.72	31.69	31.74
	SD	0.21	0.22	0.22	0.23	0.25	0.25	0.24	0.21
	Range	31.26 - 32.06	31.26 - 32.13	31.23 - 32.03	31.26 - 32.06	31.19 - 32.12	31.03 - 32.16	31.16 - 32.12	31.23 - 32.06
	n	120	120	120	120	120	120	120	120
Temp	(^{0}C)	27.9	28.0	28.1	28.1	31.0	31.1	30.9	31.0
	SD	0.4	0.4	0.5	0.2	0.4	0.5	0.3	0.5
	Range	27.2 - 29.6	27.0 - 29.0	27.1 - 30.2	27.7 - 28.7	30.0 - 32.2	30.4 - 32.5	30.1 - 31.7	30.0 - 33.0
	n	120	120	120	120	120	120	120	120
$pH_{M\text{ - }NBS}$		8.30	8.20	8.01	7.31	8.34	8.21	8.00	7.29
	SD	0.11	0.09	0.34	0.07	0.12	0.11	0.12	0.10
	Range	8.03 - 8.46	7.93 - 8.33	7.62 - 11.62	7.13 - 7.45	7.97 - 8.55	7.94 - 8.51	7.61 - 8.20	7.12 - 7.53
	n	120	120	120	120	120	120	120	120
TA	(µM)	2052	2081	2092	2131	2101	2077	2082	2123
	SD	43	17	37	25	32	32	35	22
	Range	1947 - 2104	2053 - 2121	2012 - 2128	2076 - 2160	2048 - 2152	2010 - 2125	2021 - 2134	2071 - 2148
	n	29	30	30	30	29	30	30	30
DIC	(µM)	1708	1788	1901	2156	1710	1773	1865	2135
	SD	78	52	46	34	57	80	42	28
	Range	1551 - 1829	1702 - 1859	1830 - 1981	2082 - 2217	1611 - 1795	1625 - 1905	1757 - 1917	2084 - 2194
	n	29	30	30	30	29	30	30	30

Table S2. Average measured parameters for all treatments: salinity (Sal), temperature (Temp), pH, total alkalinity (TA), and dissolved inorganic carbon (DIC). ‘SD’ represents standard deviation and ‘n’ is the sample size.

		CALCULATED PARAMETERS							
$pCO_{2\,(gas\text{-}e)}$	(µatm-v)	311	405	701	3309	288	447	673	3285
	SD	96	91	94	414	65	152	104	484
	Range	165 - 520	252 - 553	555 - 981	2442 - 4299	214 - 416	236 - 792	462 - 879	2681 - 4438
	n	29	30	30	30	29	30	30	30
$pH_{c\text{ - }NBS}$		8.27	8.18	7.97	7.37	8.29	8.15	7.99	7.38
	SD	0.10	0.08	0.05	0.05	0.07	0.11	0.06	0.06
	Range	8.07 - 8.45	8.06 - 8.33	7.85 - 8.05	7.25 - 7.48	8.16 - 8.38	7.93 - 8.34	7.89 - 8.11	7.25 - 7.46
	n	29	30	30	30	29	30	30	30
$[CO_3^{2-}]$	(µM)	241	209	145	42	274	217	162	47
	SD	39	28	12	5	31	40	18	6
	Range	173 - 312	170 - 260	115 - 164	32 - 54	217 - 315	144 - 288	129 - 195	34 - 57
	n	29	30	30	30	29	30	30	30
$[HCO_3^-]$	(µM)	1459	1568	1737	2029	1429	1545	1687	2009
	SD	109	77	51	29	82	114	51	23
	Range	1235 - 1643	1435 - 1666	1652 - 1841	1967 - 2076	1301 - 1553	1332 - 1742	1551 - 1748	1965 - 2052
	n	29	30	30	30	29	30	30	30
$[CO_2]_{(SW)}$	(µM)	8	10	18	85	7	11	16	79
	SD	2	2	2	11	2	4	2	12
	Range	4 - 13	7 - 14	14 - 25	63 - 111	5 - 10	6 - 19	11 - 21	64 - 109
	n	29	30	30	30	29	30	30	30
Ω_A		4.0	3.4	2.4	0.7	4.6	3.6	2.7	0.8
	SD	0.6	0.5	0.2	0.1	0.5	0.7	0.3	0.1
	Range	2.8 - 5.1	2.8 - 4.3	1.9 - 2.7	0.5 - 0.9	3.6 - 5.2	2.4 - 4.8	2.2 - 3.3	0.6 - 0.9
	n	29	30	30	30	29	30	30	30

Table S3. Average measured parameters for all treatments: pCO_2 of the mixed gases in equilibrium with seawaters ($pCO_{2\,(gas\text{-}e)}$); calculated pH (pH_c); carbonate ion concentration ($[CO_3^{2-}]$); bicarbonate ion concentration ($[HCO_3^-]$); dissolved carbon dioxide ($[CO_2]_{SW}$); and aragonite saturation state (Ω_A). 'SD' represents standard deviation and 'n' is the sample size.

Model	AIC	df
Temperature * Reef	547.1589	30
Reef	544.7238	28
Temperature	543.9792	28
Reef * $p$$CO_2$ * Temperature	518.2214	42
Species * Reef	516.6978	34
$p$$CO_2$ * Reef	515.3819	34
$p$$CO_2$	513.098	30
Temperature * $p$$CO_2$	513.0306	34
Species	511.1664	30
Species * Temperature * Reef	504.489	41
Species * $p$$CO_2$ * Reef	499.5312	58
Species * $p$$CO_2$ * Reef + Temperature	498.1238	59
Species * Temperature	492.3108	34
Species * $p$$CO_2$ + Temperature + Reef	489.3416	44
Species * $p$$CO_2$	488.9852	42
Species * $p$$CO_2$ * Temperature * Reef	488.7633	83
Species * $p$$CO_2$ + Temperature	487.5364	43
$p$$CO_2$ * Temperature * Reef + Species	485.5782	45
Species * Reef + $p$$CO_2$ + Temperature	482.4133	38
Species + $p$$CO_2$ * Temperature + Reef	482.0936	38
Species + $p$$CO_2$ + Temperature * Reef	480.308	36
$p$$CO_2$ * Temperature + Species	480.2898	37
Species + $p$$CO_2$ + Temperature + Reef	479.0823	35
$p$$CO_2$ * Reef + Species + Temperature	478.468	38
Species * $p$$CO_2$ * Temperature + Reef	478.147	57
Species + $p$$CO_2$ + Temperature	477.2865	34
Species * $p$$CO_2$ * Temperature	476.2514	56
Species * Temperature * Reef + $p$$CO_2$	473.9069	44
Species * ($p$$CO_2$ + Temperature)	**469.7398**	**46**
Species * Temperature + Reef + $p$$CO_2$	465.0223	38
Species * Temperature + $p$$CO_2$	463.0429	37

Table S4. Model table displaying AIC and degrees of freedom (df) for all model interaction combinations. The model combination in bold is the final model used in this analysis.

Species	Treatment		N	Mean Calcification (mg cm^2 day^{-1})	Lower 95% CI	Upper 95% CI
S. siderea	28°C	311 µatm	10	1.080	0.929	1.331
		405 µatm	12	1.290	1.147	1.439
		701 µatm	11	1.068	0.965	1.197
		3309 µatm	12	0.284	0.181	0.381
	31°C	288 µatm	8	1.038	0.876	1.248
		447 µatm	11	1.247	1.107	1.432
		673 µatm	11	1.026	0.885	1.201
		3285 µatm	12	0.242	0.081	0.360
P. strigosa	28°C	311 µatm	15	1.212	1.071	1.327
		405 µatm	5	0.505	0.271	0.798
		701 µatm	14	0.670	0.529	0.799
		3309 µatm	16	0.202	0.073	0.361
	31°C	288 µatm	9	0.226	0.043	0.344
		447 µatm	6	−0.481	−0.880	−0.232
		673 µatm	7	−0.316	−0.505	−0.188
		3285 µatm	8	−0.784	−0.921	−0.649
P. astreoides	28°C	311 µatm	11	0.099	−0.079	0.206
		405 µatm	12	0.011	−0.191	0.158
		701 µatm	10	−0.152	−0.326	0.009
		3309 µatm	12	−0.676	−0.817	−0.542
	31°C	288 µatm	6	0.247	0.066	0.376
		447 µatm	8	0.160	−0.031	0.318
		673 µatm	9	−0.003	−0.188	0.091
		3285 µatm	4	−0.527	−0.753	−0.319
U. tenuifolia	28°C	311 µatm	11	0.134	−0.102	0.399
		405 µatm	7	0.252	0.036	0.492
		701 µatm	4	0.097	−0.095	0.426
		3309 µatm	5	−0.203	−0.501	0.091
	31°C	288 µatm	4	0.167	−0.245	0.585
		447 µatm	0	NA	NA	NA
		673 µatm	1	0.129	−0.324	0.740
		3285 µatm	0	NA	NA	NA

Table S5. Bootstrapped modelled mean calcification rate for each species in all pCO$_2$ and temperature treatments reported in mg cm^2 day^{-1}. Sample sizes (N) and 95% confidence intervals (CI) are reporter for each modelled mean calcification rate (figure 1).

Fixed effect	Value	SE	t-value
(Intercept)	1.11	0.22	4.93
Species (PSTR)	0.11	0.31	0.36
Species (PAST)	−1.01	0.30	−3.32
Species (UTEN)	−0.98	0.33	−2.99
$pCO_{2\ \text{- current}}$	0.15	0.23	0.66
$pCO_{2\ \text{- end-of-century}}$	−0.03	0.20	−0.16
$pCO_{2\ \text{- extreme}}$	−0.82	0.19	−4.18
Temperature (31ºC)	−0.04	0.15	−0.25
Species (PSTR) * $pCO_{2\ \text{- current}}$	−0.83	0.34	−2.49
Species (PAST) * $pCO_{2\ \text{- current}}$	−0.25	0.31	−0.80
Species (UTEN) * $pCO_{2\ \text{- current}}$	−0.04	0.36	−0.12
Species (PSTR) * $pCO_{2\ \text{- end-of-century}}$	−0.48	0.26	−1.82
Species (PAST) * $pCO_{2\ \text{- end-of-century}}$	−0.27	0.26	−1.04
Species (UTEN) * $pCO_{2\ \text{- end-of-century}}$	−0.07	0.31	−0.23
Species (PSTR) * $pCO_{2\ \text{- extreme}}$	−0.20	0.26	−0.76
Species (PAST) * $pCO_{2\ \text{- extreme}}$	0.04	0.26	0.17
Species (UTEN) * $pCO_{2\ \text{- extreme}}$	0.45	0.31	1.43
Species (PSTR) * Temperature (31ºC)	−0.97	0.21	−4.61
Species (PAST) * Temperature (31ºC)	0.19	0.20	0.95
Species (UTEN) * Temperature (31ºC)	0.04	0.28	0.16
Colony (intercept)	0.37		
$pCO_{2\ \text{- current}}$	0.53		
$pCO_{2\ \text{- end-of-century}}$	0.33		
$pCO_{2\ \text{- extreme}}$	0.34		
Temperature (31ºC)	0.31		
Tank (Intercept)	0.04		
Species (PSTR)	0.25		
Species (PAST)	0.21		
Species (UTEN)	0.19		
Residual	0.38		

Table S6. Summary output of the linear mixed effects model used to determine the relationship between calcification rates, pCO_2, and temperature for all four coral species. Temperature and pCO_2 were treated as factors.

Treatment	**Mean Random Effect Correlation**	**Lower 95% CI**	**Upper 95% CI**
Current pCO_2	-0.653	−0.828	−0.001
End-of-century pCO_2	-0.868	−0.988	−0.517
Extreme pCO_2	-0.796	−0.967	−0.449
31°C Temperature	-0.917	−0.988	−0.467

Table S7. Mean random effect correlations of colony on calcification rates for each treatment compared to the base treatment of pre-industrial pCO_2 at 28°C with 95% confidence intervals. Non-overlapping zero intervals denotes significant effects of colony on calcification rates per treatment.

Species	Treatment		N	Mean LE (mm day^{-1})	Lower 95% CI	Upper 95% CI
S. siderea	28°C	311 μatm	11	8.09E−03	6.94E−03	9.25E−03
		405 μatm	9	8.55E-−03	7.56E−03	9.55E−03
		701 μatm	11	8.56E−03	7.54E−03	9.55E−03
		3309 μatm	12	7.01E−03	6.08E−03	7.94E−03
	31°C	288 μatm	10	6.46E−03	5.28E−03	7.68E−03
		447 μatm	8	6.75E−03	5.63E−03	7.84E−03
		673 μatm	11	7.51E−03	6.54E−03	8.50E−03
		3285 μatm	12	6.76E−03	5.82E−03	7.69E−03
P. astreoides	28°C	311 μatm	9	5.02E−03	3.93E−03	6.15E−03
		405 μatm	9	4.78E−03	3.70E−03	5.87E−03
		701 μatm	9	5.24E−03	4.11E−03	6.35E−03
		3309 μatm	12	3.34E−03	2.41E−03	4.25E−03
	31°C	288 μatm	7	6.81E−03	5.38E−03	8.25E−03
		447 μatm	5	4.16E−03	2.91E−03	5.41E−03
		673 μatm	6	3.13E−03	1.84E−03	4.48E−03
		3285 μatm	1	2.92E−03	−3.54E−04	6.07E−03

Table S8. Bootstrapped modelled mean linear extension for each species in all pCO_2 and temperature treatments reported in mm day^{-1}. Sample sizes (N) and 95% confidence intervals (CI) are reporter for each mean extension rate (figure 2).

Fixed effect	Estimate	SE	*t*-value
Intercept	8.03E−03	9.72E−04	8.256
Species (PAST)	−2.95E−03	1.15E−03	−2.555
$p\mathrm{CO}_{2\text{ - current}}$	5.34E−04	1.17E−03	0.458
$p\mathrm{CO}_{2\text{ - end-of-century}}$	4.86E−04	1.17E−03	0.416
$p\mathrm{CO}_{2\text{ - extreme}}$	−1.03E−03	1.16E−03	−0.887
Temperature (31°C)	−1.78E−03	1.22E−03	−1.459
Species (PAST) * $p\mathrm{CO}_{2\text{ - current}}$	−8.64E−04	1.45E−03	−0.597
Species (PAST) * $p\mathrm{CO}_{2\text{ - end-of-century}}$	−2.93E−04	1.44E−03	−0.203
Species (PAST) * $p\mathrm{CO}_{2\text{ - extreme}}$	−7.18E−04	1.41E−03	−0.511
Species (PAST) * Temperature (31°C)	3.48E−03	1.58E−03	2.211
$p\mathrm{CO}_{2\text{ - current}}$ * Temperature (31°C)	−6.30E−05	1.69E−03	−0.037
$p\mathrm{CO}_{2\text{ - EOC}}$ * Temperature (31°C)	7.92E−04	1.67E−03	0.474
$p\mathrm{CO}_{2\text{ - extreme}}$ * Temperature (31°C)	1.53E−03	1.65E−03	0.925
Species (PAST) * $p\mathrm{CO}_{2\text{ - current}}$ * Temperature (31°C)	−2.27E−03	2.17E−03	−1.046
Species (PAST) * $p\mathrm{CO}_{2\text{ - EOC}}$ * Temperature (31°C)	−4.71E−03	2.16E−03	−2.182
Species (PAST) * $p\mathrm{CO}_{2\text{ - extreme}}$ * Temperature (31°C)	−3.84E−03	2.70E−03	−1.423
Tank	1.32E−06		
Colony	1.68E−06		
Residual	2.75E−06		

Table S9. Summary output of the linear mixed effects model used to determine the relationship between linear extension, $p\mathrm{CO}_2$ and temperature for *S. siderea* and *P. astreoides* (PAST). Temperature and $p\mathrm{CO}_2$ were treated as factors.

Species	Treatment		T0	T30	T60	T90
S. siderea	28°C	311 µatm	10	10	10	10
		405 µatm	12	12	12	12
		701 µatm	11	11	11	11
		3309 µatm	12	12	12	12
	31°C	288 µatm	8	8	8	8
		447 µatm	11	11	11	11
		673 µatm	12	11	11	11
		3285 µatm	12	12	12	12
P. strigosa	28°C	311 µatm	16	16	15	15
		405 µatm	8	6	5	5
		701 µatm	14	14	14	14
		3309 µatm	16	16	16	16
	31°C	288 µatm	14	11	9	9
		447 µatm	13	11	6	6
		673 µatm	15	13	7	7
		3285 µatm	13	11	8	8
P. astreoides	28°C	311 µatm	11	11	11	11
		405 µatm	12	12	12	12
		701 µatm	12	11	10	10
		3309 µatm	12	12	12	12
	31°C	288 µatm	11	8	6	6
		447 µatm	9	8	8	8
		673 µatm	12	12	9	9
		3285 µatm	10	6	4	4
U. tenuifolia	28°C	311 µatm	12	11	11	11
		405 µatm	7	7	7	7
		701 µatm	8	5	4	4
		3309 µatm	8	6	5	5
	31°C	288 µatm	8	8	4	4
		447 µatm	1	0	0	0
		673 µatm	4	2	1	1
		3285 µatm	0	0	0	0

Table S10. Sample size surviving for each species at each time point per treatment used for constructing survival curves (figure S6).

Species	Fixed Effect	Hazard rate	Hazard ratio	Hazard ratio SE	*z*	*P*
S. siderea	pCO$_2$	−5.39E-06	1.00	0.00	0	1.00
	Temperature (31^{o}C)	22.09	3.92E+09	0.00	Inf	0.00
	pCO$_2$ * Temperature (31^{o}C)	−5.87E-04	1.00	0.00	−Inf	0.00
P. strigosa	pCO$_2$	−3.72E−03	1.00	0.00	−1.02	0.31
	Temperature (31^{o}C)	0.58	1.79	1.51	0.39	0.70
	pCO$_2$ * Temperature (31^{o}C)	3.54E−03	1.00	0.00	0.97	0.33
P. astreoides	pCO$_2$	3.12E−04	1.00	0.00	1.20	0.23
	Temperature (31^{o}C)	0.47	1.60	1.17	0.40	0.69
	pCO$_2$ * Temperature (31^{o}C)	3.28E−03	1.00	0.00	1.52	0.13
U. tenuifolia	pCO$_2$	3.41E−04	1.00	2.66E−04	1.28	0.20
	Temperature (31^{o}C)	0.52	1.68	1.17	0.44	0.66
	pCO$_2$ * Temperature (31^{o}C)	3.26E−03	1.00	2.17E−03	1.51	0.13

Table S11. Cox mixed effects proportional hazards analysis for survival of all four species. The ‘hazard rate’ represents the modelled risk of death, so that positive values represent increased risk. The ‘hazard ratio’ indicates the hazard in the treatment compared to the control.

Species	Fixed Effect	loglik	χ^2	DF	*P*
S. siderea	*NULL*	−4.48			
	pCO$_2$	−4.34	0.27	1	0.6
	Temperature (31ºC)	−3.61	1.47	1	0.23
	Reef environment	−2.94	1.35	1	0.225
	pCO$_2$ * Temperature (31ºC)	−3.61	0	1	1
P. strigosa	*NULL*	−131.95			
	pCO$_2$	−121.63	20.64	1	5.53E−06 ***
	Temperature (31ºC)	−113.32	16.61	1	4.60E−05 ***
	Reef environment	−113.29	0.07	1	0.79
	pCO$_2$ * Temperature (31ºC)	−111.80	3.06	1	0.08
P. astreoides	*NULL*	−74.67			
	pCO$_2$	−73.25	2.84	1	0.09
	Temperature (31ºC)	−66.06	14.38	1	1.49E−04 ***
	Reef environment	−64.55	3.02	1	0.08
	pCO$_2$ * Temperature (31ºC)	−65.41	1.3	1	0.25
U. tenuifolia	*NULL*	−59.12			
	pCO$_2$	−58.36	1.5	1	0.22
	Temperature (31ºC)	−54.28	8.18	1	4.24E−03 **
	Reef environment	−54.16	0.24	1	0.63
	pCO$_2$ * Temperature (31ºC)	−53.49	1.56	1	0.21

Table S12. Statistical outcomes for coral survival analyses of all four species, using Cox mixed effects proportional hazards models.

Species	Reef Environment	Treatment		N	Mean Calcification (mg cm^2 day^{-1})	CI
S. siderea	**Offshore**	28°C	311 µatm	6	1.263	0.181
			405 µatm	6	1.207	0.171
			701 µatm	5	1.068	0.153
			3309 µatm	6	0.092	0.249
		31°C	288 µatm	3	1.083	0.191
			447 µatm	4	1.051	0.182
			673 µatm	4	0.970	0.159
			3285 µatm	0	0.405	0.250
	Inshore	28°C	311 µatm	5	1.329	0.182
			405 µatm	6	1.273	0.174
			701 µatm	5	1.134	0.162
			3309 µatm	6	0.158	0.252
		31°C	288 µatm	3	1.149	0.194
			447 µatm	4	1.117	0.183
			673 µatm	5	1.036	0.169
			3285 µatm	4	0.471	0.257
P. strigosa	**Offshore**	28°C	311 µatm	10	0.942	0.178
			405 µatm	3	0.901	0.172
			701 µatm	8	0.798	0.162
			3309 µatm	10	0.077	0.218
		31°C	288 µatm	5	−0.308	0.238
			447 µatm	3	−0.332	0.230
			673 µatm	4	−0.392	0.208
			3285 µatm	5	−0.810	0.326
	Inshore	28°C	311 µatm	5	1.008	0.194
			405 µatm	2	0.966	0.186
			701 µatm	6	0.863	0.170
			3309 µatm	6	0.142	0.220
		31°C	288 µatm	4	−0.242	0.240
			447 µatm	3	−0.266	0.231
			673 µatm	3	−0.326	0.212
			3285 µatm	3	−0.744	0.325

Species	Reef Environment	Treatment		N	Mean Calcification (mg cm^2 day^{-1})	CI
P. astreoides	Offshore	28° C	311 µatm	6	−0.031	0.174
			405 µatm	6	−0.063	0.168
			701 µatm	6	−0.141	0.151
			3309 µatm	6	−0.692	0.261
		31° C	288 µatm	4	0.180	0.212
			447 µatm	5	0.138	0.203
			673 µatm	6	0.033	0.179
			3285 µatm	0	NA	NA
	Inshore	28° C	311 µatm	4	0.035	0.181
			405 µatm	6	0.003	0.174
			701 µatm	5	−0.075	0.158
			3309 µatm	6	−0.626	0.258
		31° C	288 µatm	4	0.246	0.213
			447 µatm	6	0.204	0.202
			673 µatm	5	0.099	0.176
			3285 µatm	6	−0.634	0.422
U. tenuifolia	Offshore	28° C	311 µatm	3	0.135	0.219
			405 µatm	2	0.115	0.214
			701 µatm	1	0.065	0.198
			3309 µatm	1	−0.287	0.404
		31° C	288 µatm	0	NA	NA
			447 µatm	0	NA	NA
			673 µatm	0	NA	NA
			3285 µatm	0	NA	NA
	Inshore	28° C	311 µatm	8	0.201	0.206
			405 µatm	5	0.181	0.194
			701 µatm	3	0.131	0.170
			3309 µatm	4	−0.222	0.377
		31° C	288 µatm	4	0.180	0.434
			447 µatm	0	NA	NA
			673 µatm	1	−0.012	0.881
			3285 µatm	0	NA	NA

Table S13. Bootstrapped modelled mean calcification rate for each species by reef environment in all pCO$_2$ and temperature treatments reported in mg cm^2 day^{-1}. Sample sizes (N) and 95% confidence intervals (CI) are reporter for each mean calcification rate (figure S10).

Species	Reef Environment	Treatment		N	Mean LE (mm day-1)	CI
S. siderea	**Offshore**	28°C	311 µatm	6	8.11E−03	7.53E−04
			405 µatm	6	8.04E−03	7.37E−04
			701 µatm	6	7.86E−03	6.67E−04
			3309 µatm	6	6.63E−03	1.01E−03
		31°C	288 µatm	4	6.50E−03	7.93E−04
			447 µatm	4	6.50E−03	7.66E−04
			673 µatm	6	6.49E−03	6.99E−04
			3285 µatm	6	6.43E−03	1.05E−03
	Inshore	28°C	311 µatm	3	6.89E−03	7.83E−04
			405 µatm	5	8.91E−03	7.56E−04
			701 µatm	5	8.73E−03	6.96E−04
			3309 µatm	6	7.50E−03	9.82E−04
		31°C	288 µatm	4	7.37E−03	7.55E−04
			447 µatm	6	7.37E−03	7.21E−04
			673 µatm	5	7.36E−03	6.45E−04
			3285 µatm	6	7.30E−03	1.05E−03
P. astreoides	**Offshore**	28°C	311 µatm	5	5.65E−03	7.94E−04
			405 µatm	3	4.57E−03	7.57E−04
			701 µatm	5	4.36E−03	6.76E−04
			3309 µatm	6	2.95E−03	1.05E−03
		31°C	288 µatm	2	4.42E−03	9.75E−04
			447 µatm	3	4.24E−03	8.73E−04
			673 µatm	3	3.82E−03	8.95E−04
			3285 µatm	0	NA	NA
	Inshore	28°C	311 µatm	4	5.52E−03	7.52E−04
			405 µatm	6	5.44E−03	7.05E−04
			701 µatm	4	5.24E−03	6.46E−04
			3309 µatm	6	3.82E−03	1.02E−03
		31°C	288 µatm	3	5.29E−03	9.64E−04
			447 µatm	4	5.11E−03	8.91E−04
			673 µatm	3	4.69E−03	7.80E−04
			3285 µatm	1	1.69E−03	3.19E−03

Table S14. Bootstrapped modelled mean linear extension for each species by reef environment in all $p\mathrm{CO_2}$ and temperature treatments reported in mm day^{-1}. Sample sizes (N) and 95% confidence intervals (CI) are reporter for each mean extension rate (figure S11).

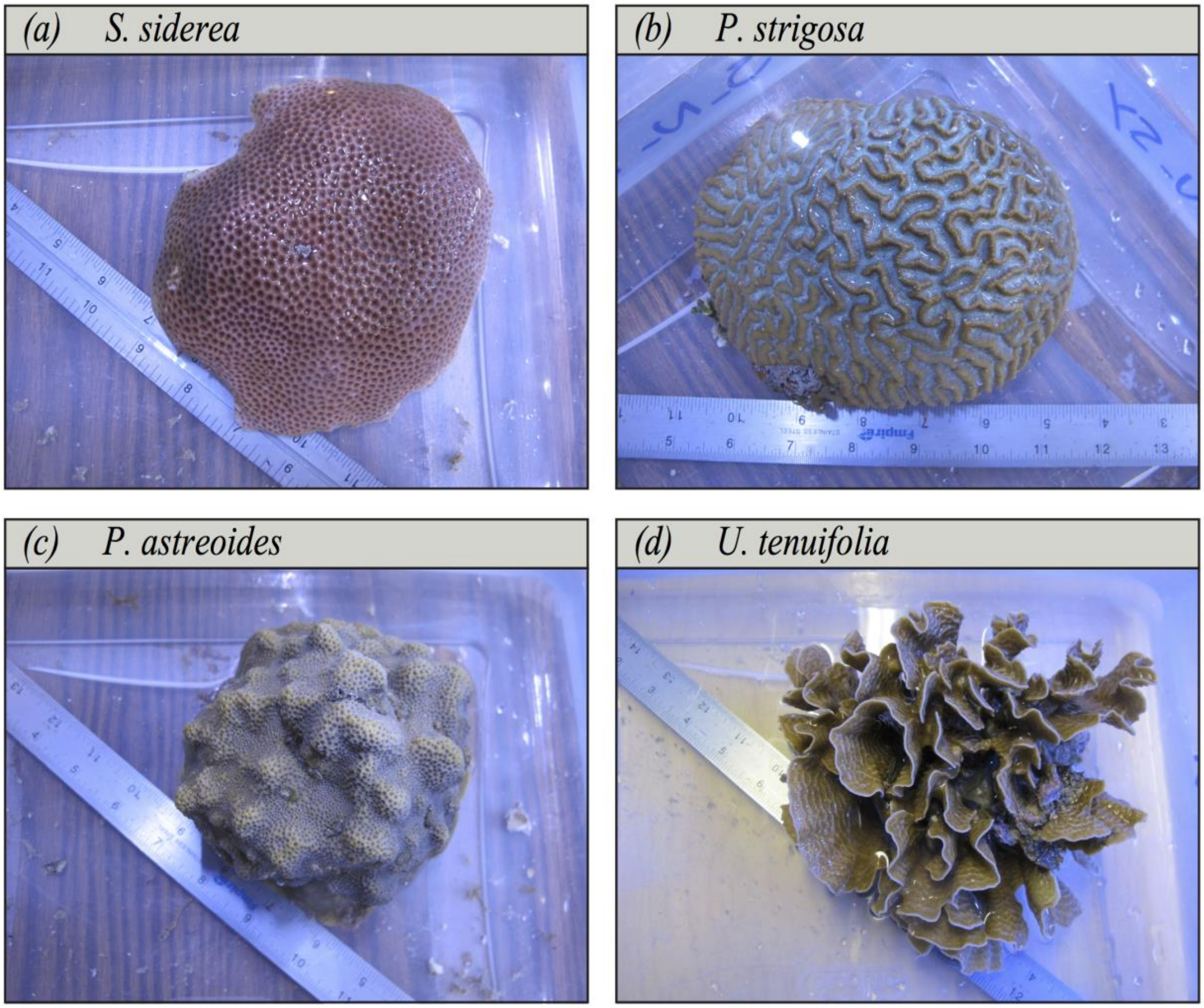

Figure S1. Representative collected colonies of (*a*) *S. siderea*, (*b*) *P. strigosa*, (*c*) *P. astreoides*, and *(d*) *U. tenuifolia* from the Belize Barrier Reef System prior to sectioning.

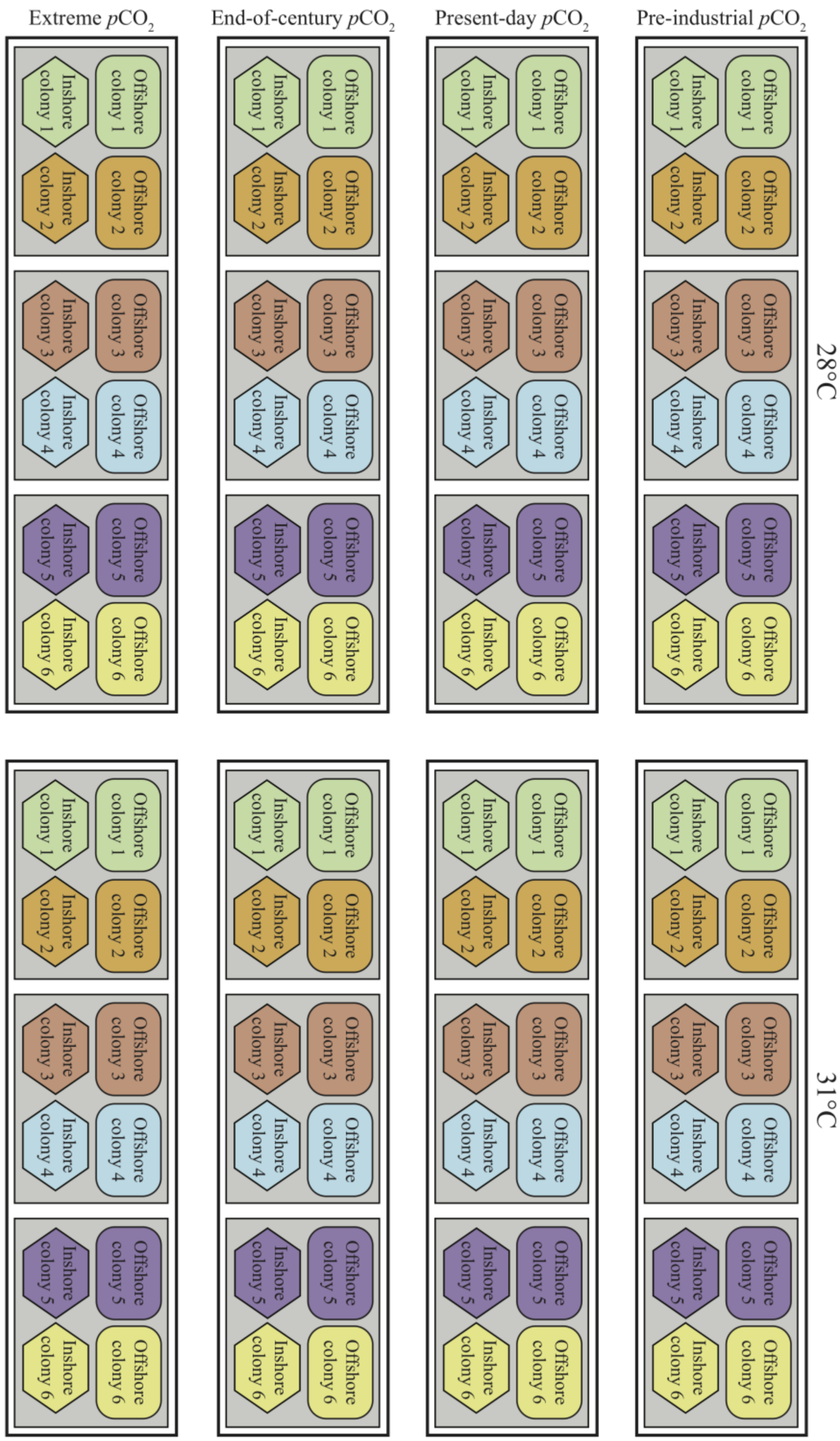

Figure S2. Diagram showing allocation of coral fragments for a single species throughout experimental tank array. Colour represent a different colony and shape represents reef environment. Four colonies (two from each reef environment) are within each tank (grey box) and three tanks make up a treatment (white box). This is repeated for each pCO$_2$ treatment at both temperatures. This same arrangement was created with all four species.

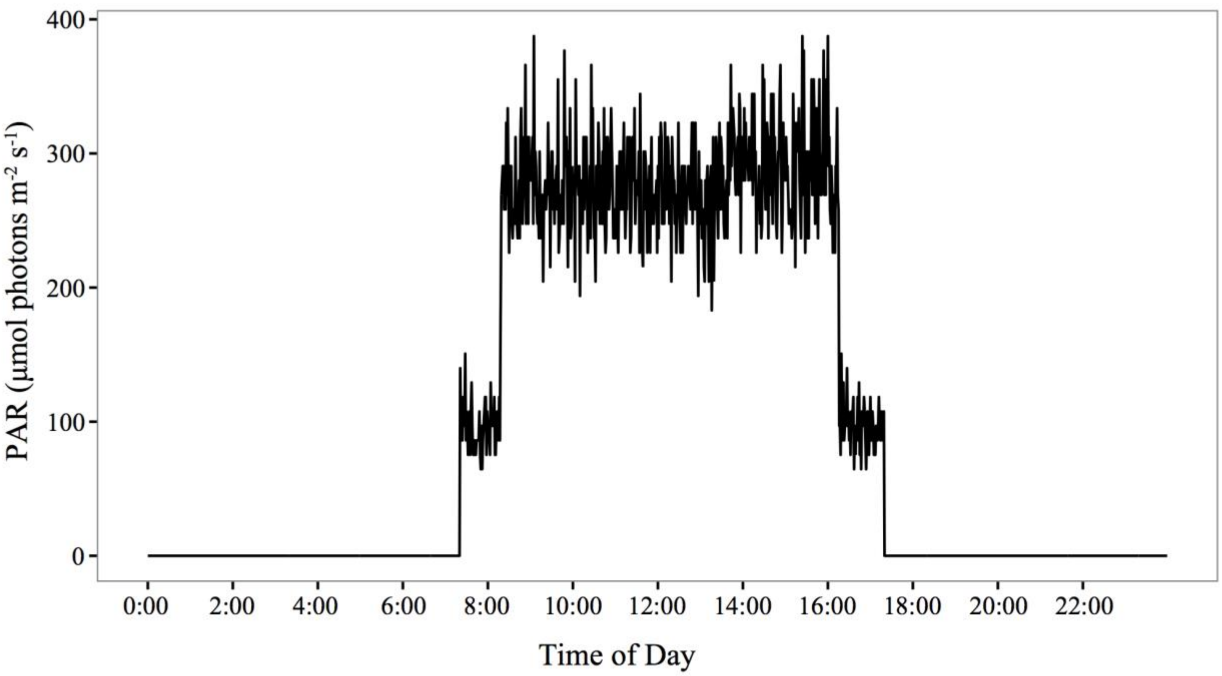

Figure S3. Ten hour light cycle for all 24 experimental treatment tanks reported in PAR (photosynthetically active radiation; μmol photons m^{-2} s^{-1}).

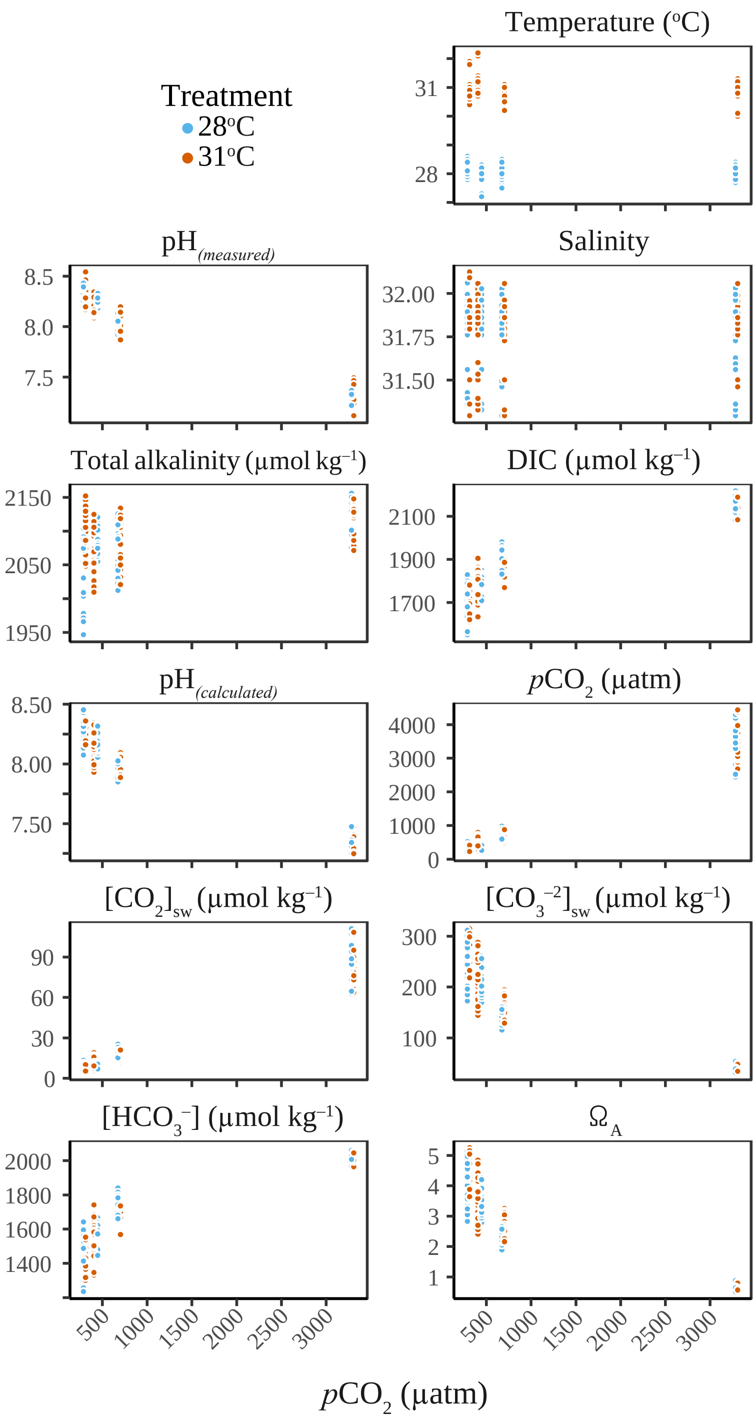

Figure S4. Calculated and measured parameters for all 24 experimental tanks over the 93-day experimental interval: (*a*) measured total alkalinity; (*b*) calculated pCO_2 of the mixed gases in equilibrium with the experimental seawaters; (*c*) calculated carbonate ion concentration; (*d*) measured dissolved inorganic carbon; (*e*) calculated bicarbonate ion concentration; (*f*) calculated dissolved carbon dioxide; (*g*) measured temperature; (*h*) calculated pH; (*i*) measured pH; (*j*) measured salinity; and (*k*) calculated aragonite saturation state.

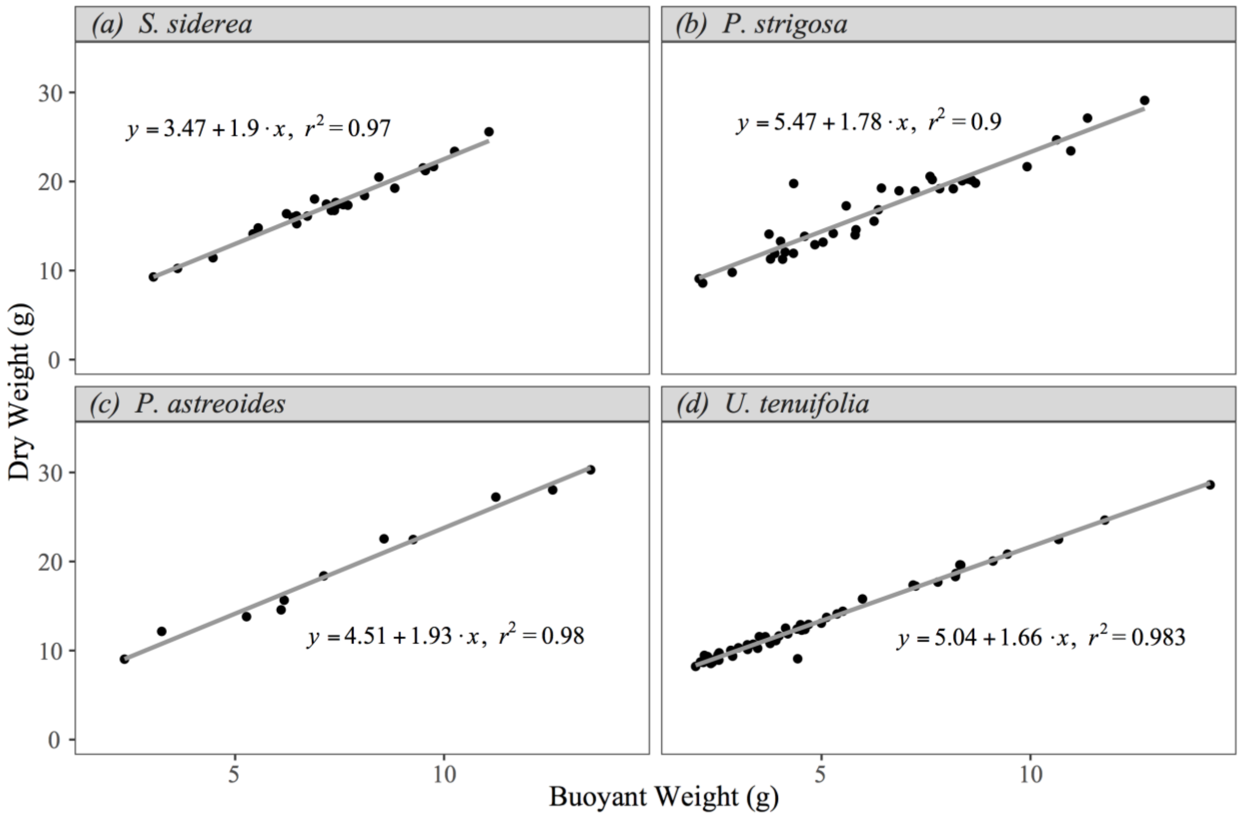

Figure S5. Linear relationship between buoyant weight (mg) and dry weight (mg) for (*a*) *S. siderea*, (*b*) *P. strigosa*, (*c*) *P. astreoides*, and *(d*) *U. tenuifolia.*

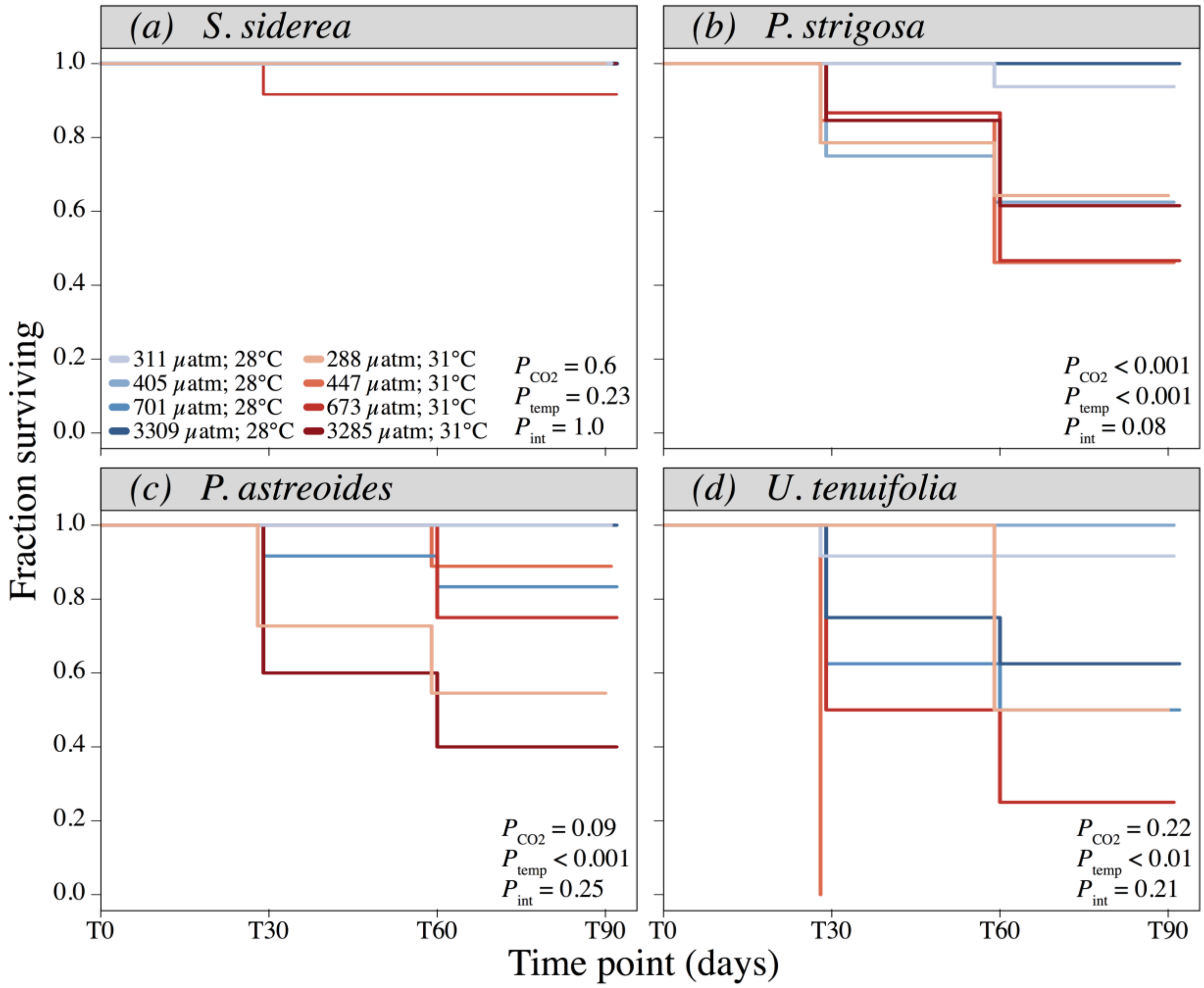

Figure S6. Fraction of fragments surviving from the start of the experiment for *S. siderea* (*a*), *P. strigosa* (*b*), *P. astreoides* (*c*), and *U. tenuifolia* (*d*). Blue represents 28°C treatments and red represents 31°C treatments. Colour intensity corresponds to pCO$_2$ level, with the lowest intensity representing pre-industrial pCO$_2$ and the highest intensity representing an extreme pCO$_2$ condition.

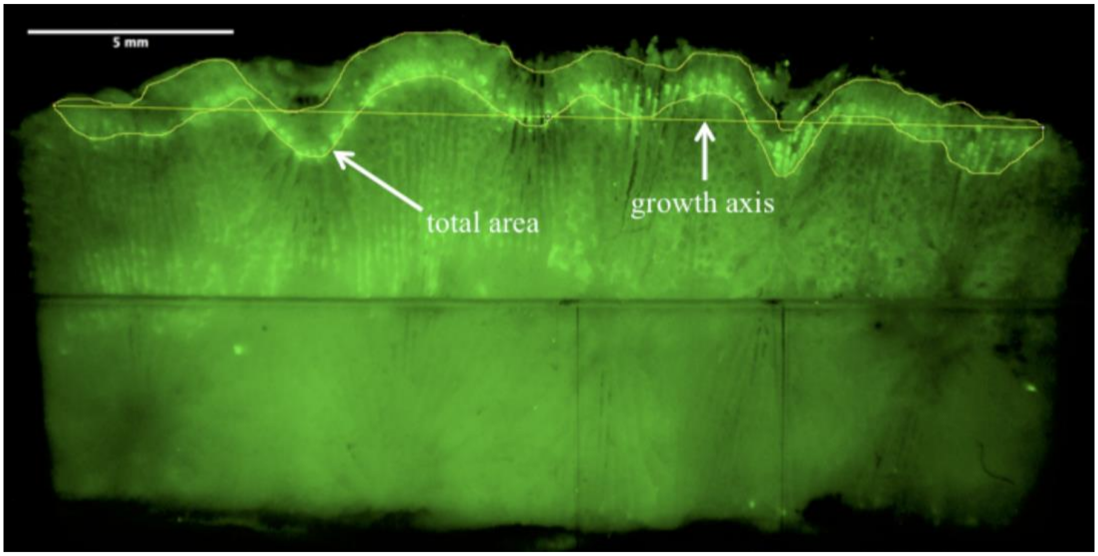

Figure S7. Example of linear extension measurement for *S. siderea* sample demonstrating total area and growth axis length determination using image software (IMAGE J).

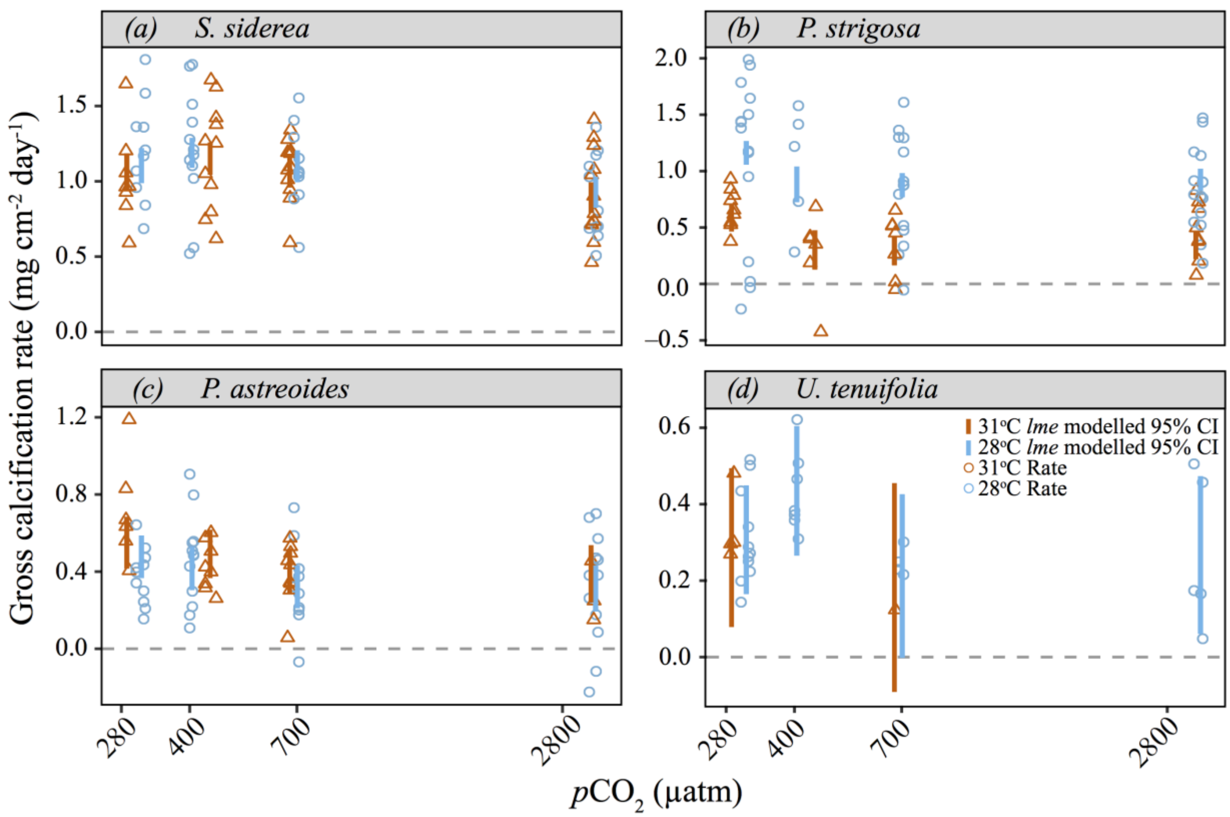

Figure S8. Modelled 95% confidence intervals of gross calcification rate for the 90-day experimental period in mg cm^{-2} day^{-1} for (*a*) *S. siderea*, (*b*) *P. strigosa*, (*c*) *P. astreoides*, and (*d*) *U. tenuifolia*. Blue bars represent 28°C treatment 95% confidence intervals and orange bars represent 31°C treatment 95% confidence intervals, with pCO$_2$ along the x-axis (µatm). Blue hollow circles represent the raw gross calcification rates for individual fragments in the 28°C treatment, and orange hollow circles are raw gross calcification rates for individual fragments in the 31°C treatment.

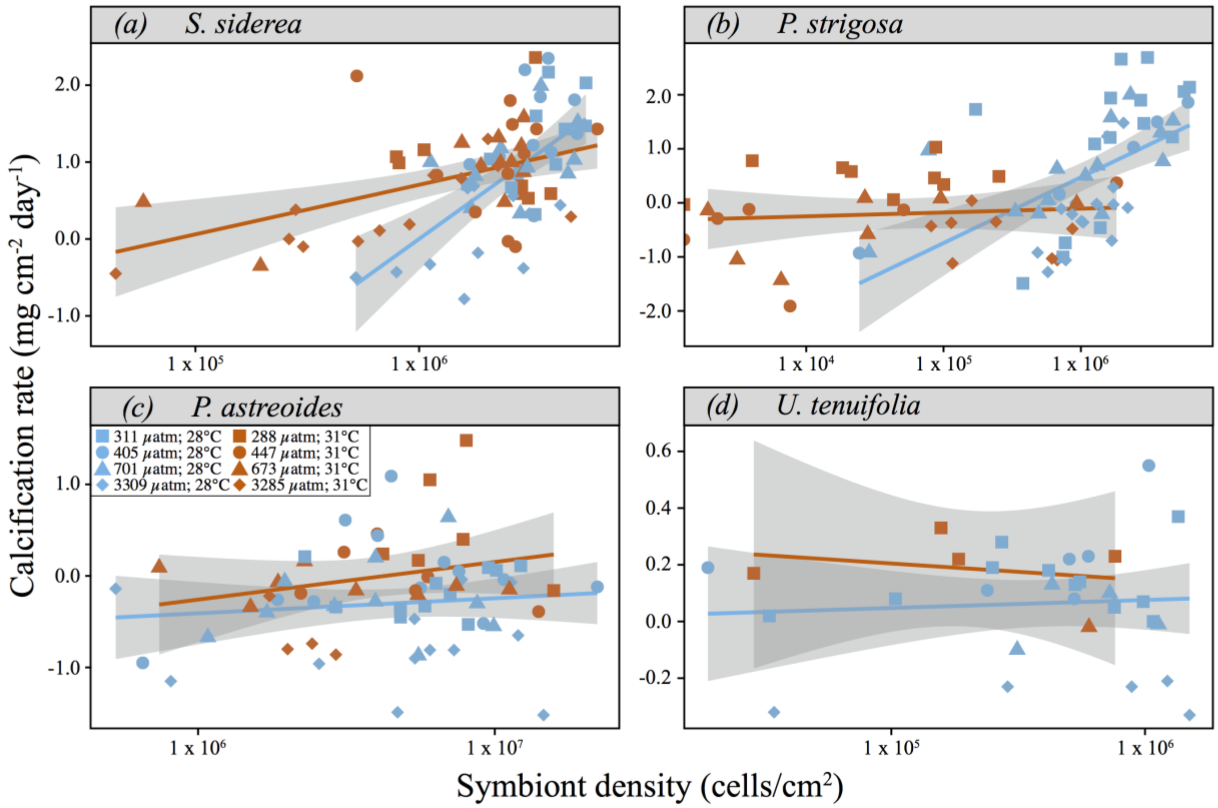

Figure S9. Relationship between calcification rate and symbiont density (cell counts/cm^2) for (*a*) *S. siderea*, (*b*) *P. strigosa*, (*c*) *P. astreoides*, and (*d*) *U. tenuifolia*. Shape represents pCO$_2$ treatments and colour represents temperature treatments. The line denotes a simple linear regression with standard error in the grey.

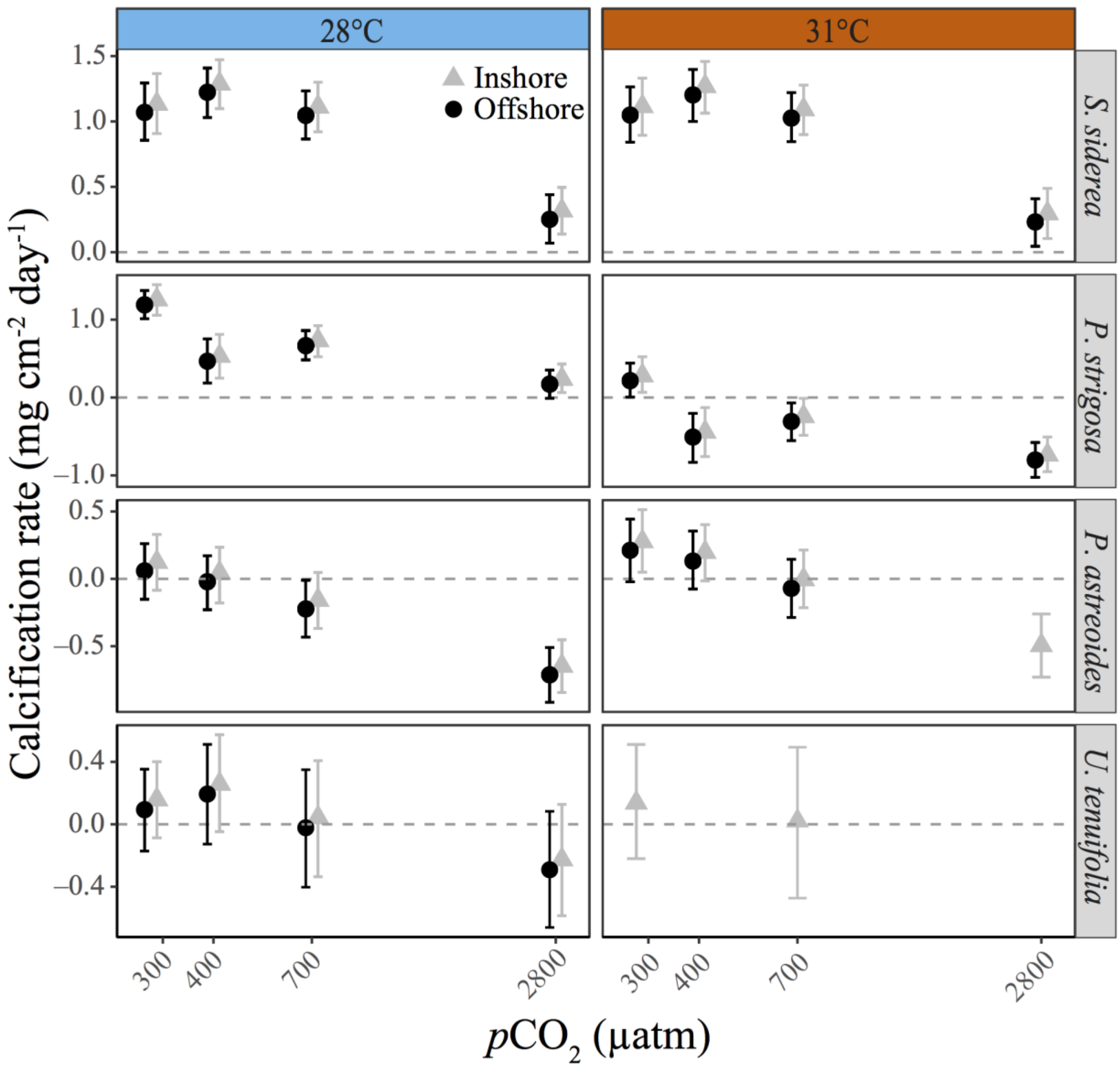

Figure S10. Modelled mean calcification rate for the 90-day experimental period in mg cm^{-2} day^{-1} separated by reef environment for (*a*) *S. siderea*, (*b*) *P. strigosa*, (*c*) *P. astreoides*, and (*d*) *U. tenuifolia*. Grey triangles denote inshore corals and black circles denote offshore corals. Left panel demonstrates mean calcification rate at 28°C and the right panel shows calcification at 31°C, with *p*CO_2 along the x-axis (µatm) on a log scale. Error bars denote 95% confidence intervals of each estimated mean.

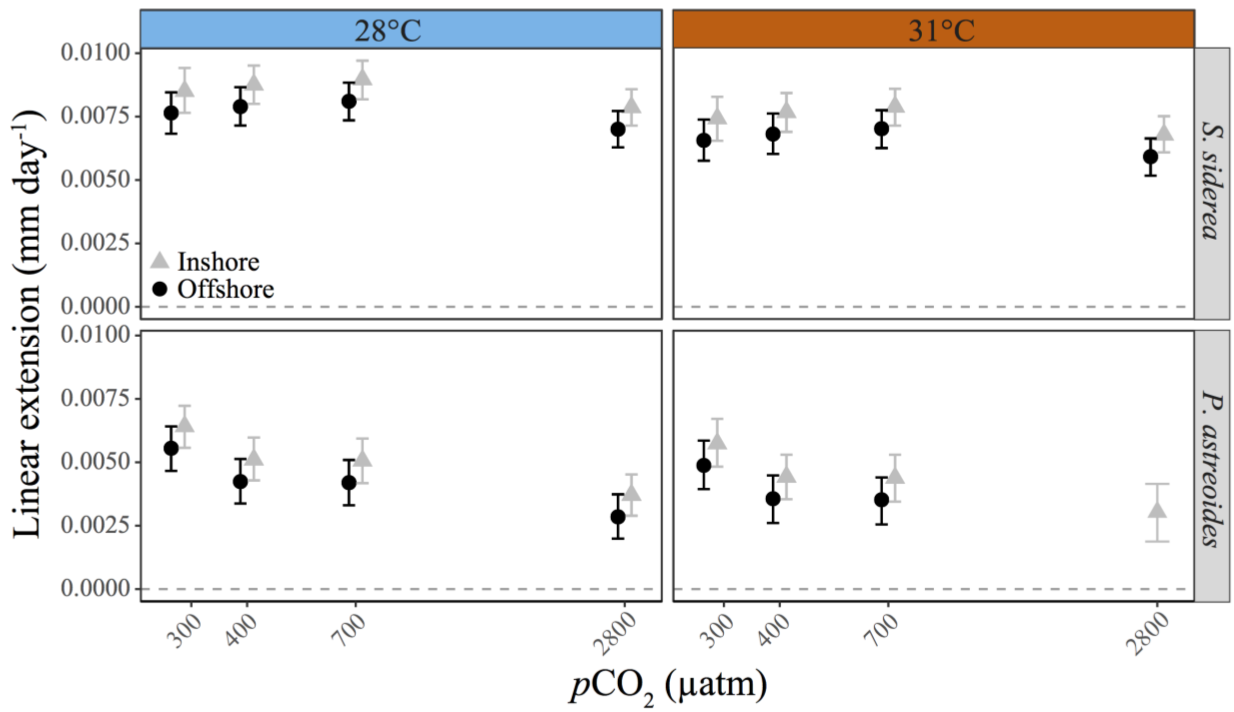

Figure S11. Modelled mean linear extension rate for the 90-day experimental period in mm cm^{-2} day^{-1} separated by reef environment for (*a*) *S. siderea* and (*b*) *P. astreoides*. Grey triangles denote inshore corals and black circles denote offshore corals. Left panel demonstrates mean calcification rate at 28°C and the right panel shows calcification at 31°C, with pCO_2 along the x-axis (µatm) on a log scale. Error bars denote 95% confidence intervals of each estimated mean.

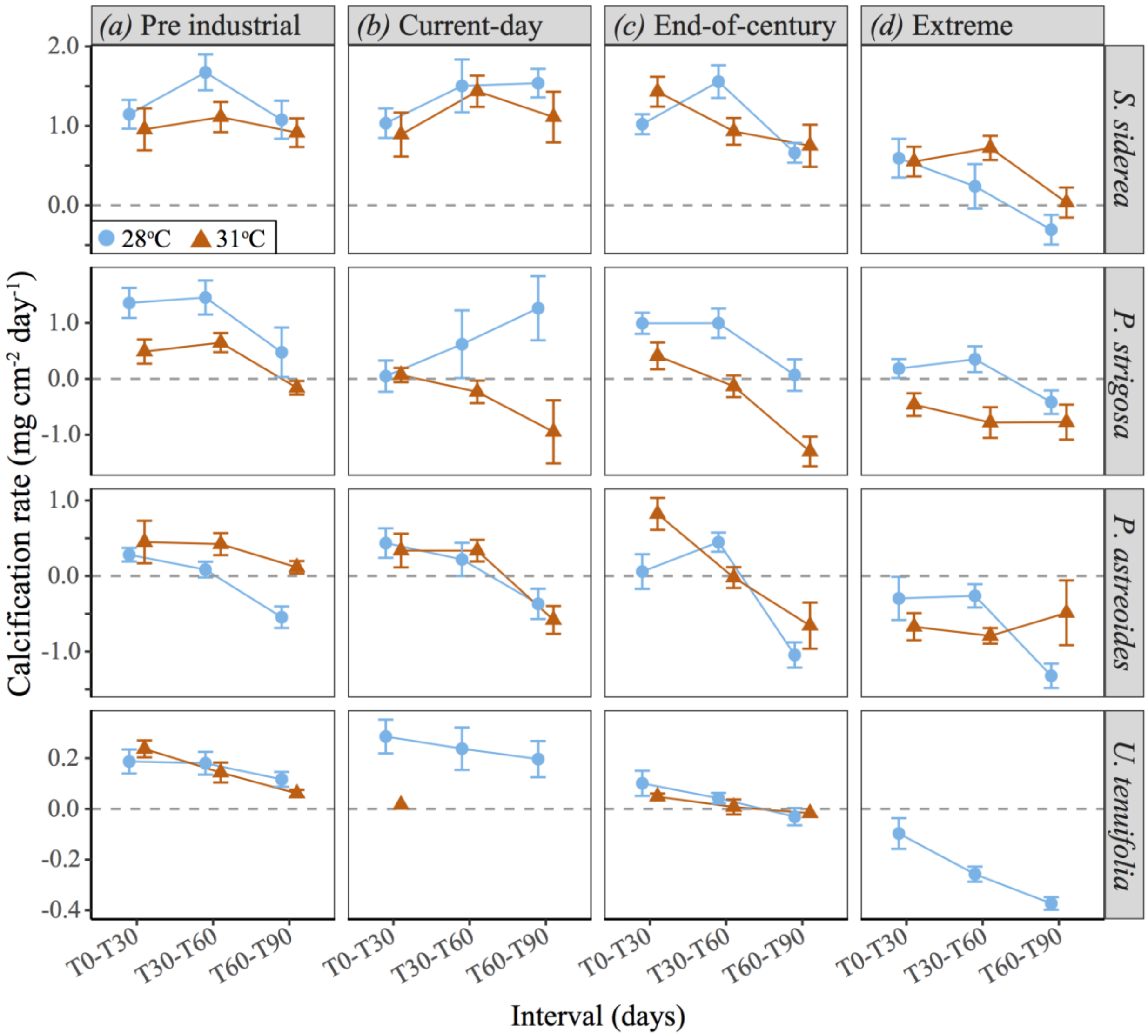

Figure S12. Mean calcification rate (mg cm^{-2} day^{-1}) at each 30-day experimental interval for all four species at (*a*) pre-industrial, (*b*) current-day, (*c*) end-of-century, and (*d*) extreme pCO_2 treatments. Blue circles represent 28ºC treatments and orange triangles represent 31ºC treatments, with time interval along the x-axis. Error bars denote standard error of each mean.

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