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SUPPLEMENTARY INFORMATION

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Shift from coral to macroalgae dominance on a volcanically acidified reef

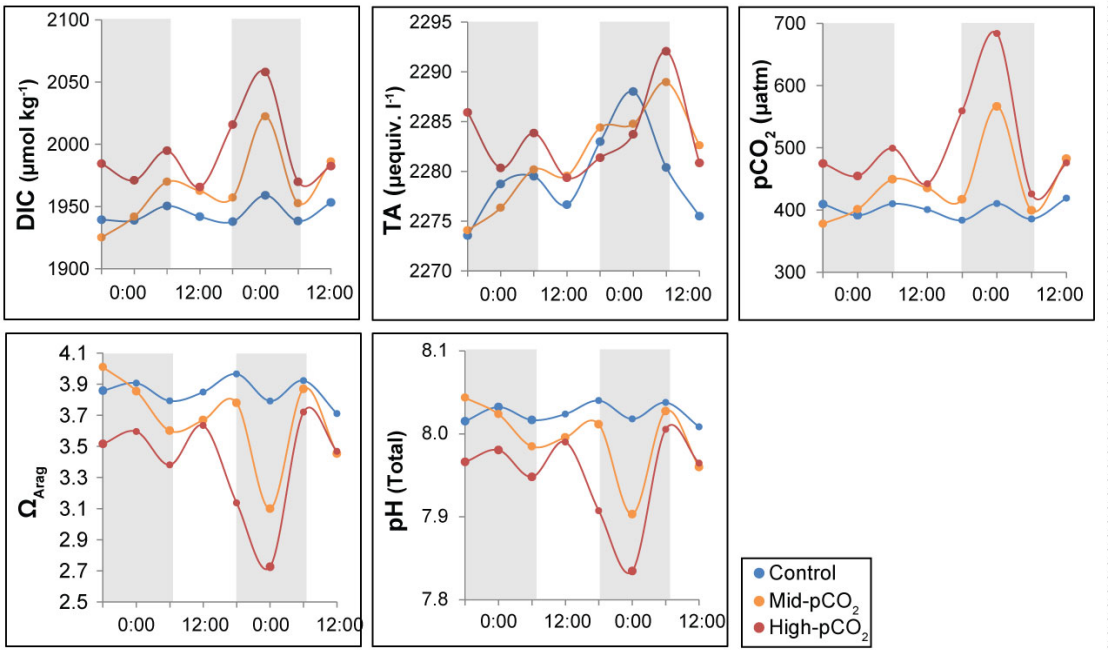

Figure S1. Diel fluctuation in carbonate chemistry as determined from discrete water samples collected immediately above the benthos at each of the three study sites.

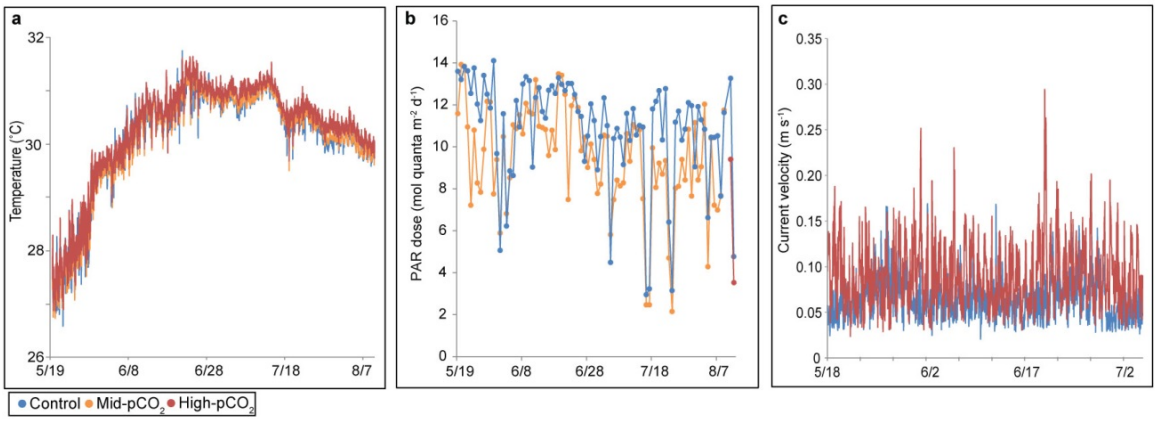

Figure S2. Environmental conditions at the control, mid-pCO_2, and high-pCO_2 sites. a, water temperature; b, daily dose of photosynthetically active radiation (PAR); c, current speed. Only two days of PAR data were available at the high-pCO_2 site.

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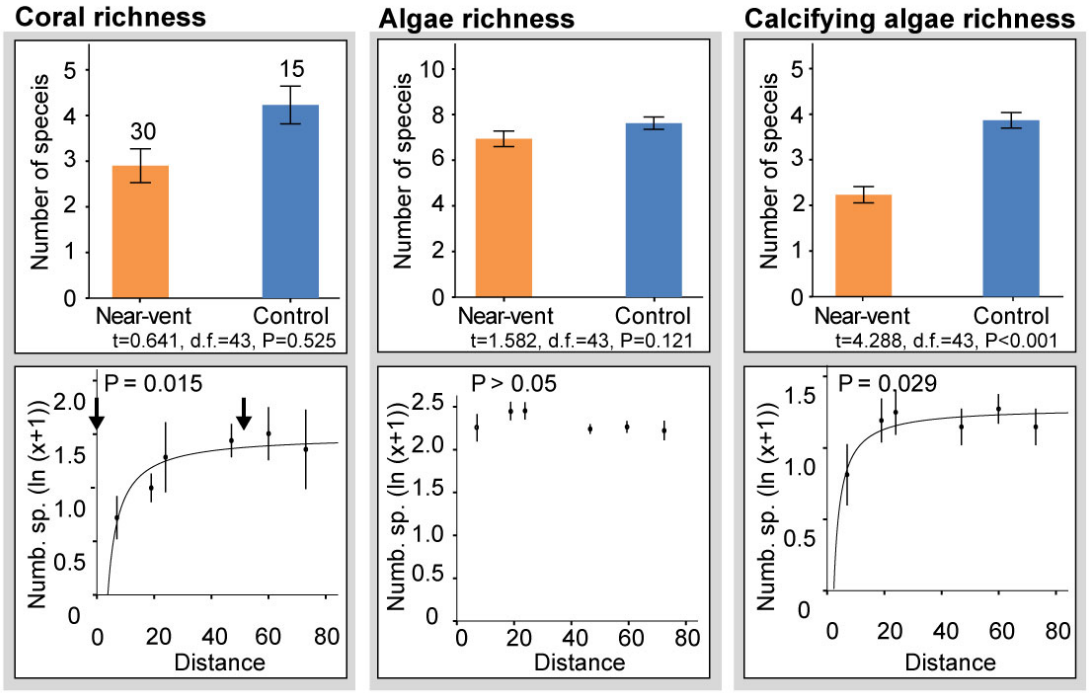

Figure S3. The richness of coral and algae communities at the control and near-vent sites (top) and regression of coral and algae richness as a function of distance (m) from the high-pCO_2 site (bottom). Arrows in the coral richness regression panel denote locations of the high-pCO_2 and mid-pCO_2 sites. In the top panels, data in the near-vent category are pooled from those in the regression analysis (bottom panels) and do not reflect the richness of the high-CO_2 site which had very low coral cover. The t-value, degrees of freedom (d.f.), and P value are given in each of the top panels. Error bars are SE. Richness data are ln (x+1) transformed. Site-specific sample sizes are in the first panel and regressions are based on five quadrats per distance.

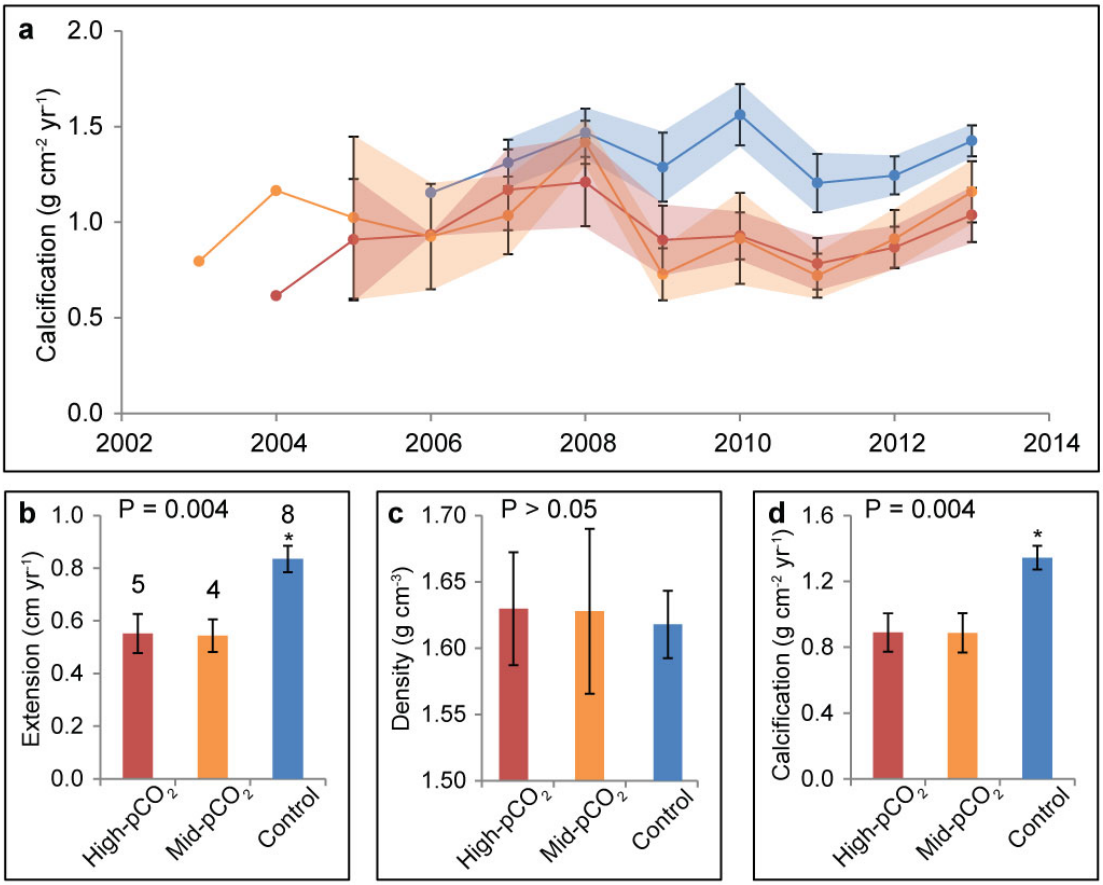

Figure S4. Response of coral calcification to elevated pCO_2. a, Mean yearly calcification of *Porites* spp. with SE around mean; b, mean skeletal extension; c, density; d, calcification and SE. P values are for GLMs and bars which share a symbol are not significantly different. Data in b-d are from the years 2009-2013 to ensure adequate and equal number of years sampled per core. Number of cores sampled per site in b. Note that corals are collected in close proximity to the instrumented study sites and are not necessarily from within the mosaics in Figure 3.

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Supplementary Tables

Table S1. Environmental conditions at each fixed monitoring site. PAR data expressed as mean daily dose as described in methods and temperature data are daily averages. PAR data from short-term 2-day PAR logger deployment marked with ST. Standard deviation in parentheses. NA, not available. n, number of samples taken per site. d.f., degrees of freedom. pH data were analyzed with a Kruskal-Wallis test, PAR with a t-test, and current with a Mann-Whitney test. Temperature data were not analyzed as differences are less than the accuracy of the instruments employed.

	pH (Total scale, n=3984)			**Temperature** (˚C, n=8381)			**PAR dose** (mol photons m^{-2}, n=83, 2^{ST})	**Currents** ($m\ s^{-1}$, n=1169)
	Mean	Min	Max	Mean	Min	Max	Mean dose	Hourly mean
Control	8.04 (0.016)	7.98	8.08	30.1 (0.98)	27.3	31.2	10.9, 9.0^{ST} (2.46), $(6.01)^{ST}$	0.06 (0.023)
Mid-pCO_2	7.98 (0.027)	7.76	8.03	30.1 (0.99)	27.3	31.2	9.5 (2.46)	NA
High-pCO_2	7.94 (0.051)	7.72	8.07	30.3 (0.98)	27.4	31.3	6.5^{ST} $(4.16)^{ST}$	0.09 (0.037)
Statistics	H=8317.2, d.f.=2, P<0.001			NA			T=3.695, d.f.=164, P<0.001	U=990947, N=2338, P<0.001

Table S2. Vent gas composition at Maug. TS is total sulfur. SE in parentheses. Measurements based on four separate gas samples.

Site	**CO_2** (%)	**O_2** (%)	**N_2** (%)	**H_2** (%)	**Ar** (%)	**CH_4** (ppm)	**C_2H_4** (ppm)	**TS** (ppb)
Maug	61.10 (10.96)	4.80 (3.29)	33.10 (8.04)	0.10 (0.05)	0.70 (0.11)	2410 (740)	0 (0)	0.09 (0.067)

Table S3. GLM analysis of arcsine transformed percent cover data, as obtained from photomosaics of three study sites.

Dependent variable	**Source**	**d.f.**	**MS**	***F***	**P**
Coral	Site	2	11.144	178.383	<0.001
	Error	297	0.062		
Fleshy macroalgae	Site	2	13.270	485.005	<0.001
	Error	297	0.027		
Turf algae	Site	2	2.640	36.985	<0.001
	Error	297	0.071		
Crustose coralline algae	Site	2	0.009	8.389	<0.001
	Error	297	0.001		

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Table S4. Regression of coral and algae parameters as a function of proximity to the high-pCO_2 vent site. Four models fitted for percent cover data and three fitted for richness data. SSE is sum of squared errors. AICc is Akaike information criterion with finite sample size correction. Best model shown in column marked best.

Model	SSE	r^2	P	AICc	Best
Coral cover					
Linear	1.325	0.241	<0.001	-306.48	Ricker
Parabolic	1.299	0.256	<0.001	-305.77	
Asymptotic	1.45	0.17	<0.001	-299.53	
Ricker Power	1.288	0.263	-	-308.66	
Fleshy macroalgae cover					
Linear	2.533	0.268	<0.001	-256.58	Ricker
Parabolic	2.104	0.392	<0.001	-268.64	
Asymptotic	1.525	0.559	<0.001	-295.65	
Ricker Power	1.503	0.566	-	-296.77	
Turf algae cover					
Linear	6.654	0.351	<0.001	-182.21	Ricker
Parabolic	5.829	0.432	<0.001	-190.18	
Asymptotic	7.232	0.295	<0.001	-175.80	
Ricker Power	5.839	0.430	-	-192.27	
Crustose coralline algae cover					
Linear	0.432	0.007	0.483	-392.77	Ricker
Parabolic	0.381	0.124	0.008	-400.22	
Asymptotic	0.415	0.044	0.068	-395.86	
Ricker Power	0.337	0.222	-	-411.99	
Coral richness					
Linear	8.441	0.153	0.033	-31.12	Asymptotic
Parabolic	7.811	0.216	0.037	-30.77	
Asymptotic	8.02	0.195	0.015	-32.65	
Algae richness					
Linear	1.543	0.054	0.218	1.543	None
Parabolic	1.499	0.081	0.032	1.499	
Asymptotic	1.630	<0.001	0.945	1.630	
Calcifying algae richness					
Linear	3.278	0.052	0.226	-59.50	Asymptotic
Parabolic	2.986	0.136	0.139	-59.62	
Asymptotic	2.91	0.158	0.029	-63.07	

Table S5. Extension, density and calcification established from cores of massive *Porites* in the vicinity of three monitoring sites. SE in parentheses.

Site	Extension	Density	Calcification	n
Control	0.84 (0.05)	1.62 (0.025)	1.34 (0.073)	8
Mid-pCO_2	0.54 (0.062)	1.63 (0.062)	0.89 (0.121)	4
High-pCO_2	0.55 (0.074)	1.63 (0.043)	0.89 (0.116)	5

Table S6. GLM analysis of the growth of massive *Porites* near the three vent sites.

Dependent variable	Source	d.f.	MS	*F*	P
Extension	Site	2	0.175	8.222	0.004
	Error	14	0.021		
Density	Site	2	0.000	0.031	0.970
	Error	14	0.008		
Calcification	Site	2	0.440	8.339	0.004
	Error	14	0.053		

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Table S7. Proportion of quadrats containing each coral species at the near-vent and control sites.

Species are ordered according to their overall prevalence at both sites.

Species	Near-vent		Control	
Montastrea valenciennesi	0.37	(0.206-0.561)	0.47	(0.223-0.726)
Leptastrea purpurea	0.50	(0.317-0.683)	0.00	(0.004-0.340)
Astreopora myriophthalma	0.30	(0.154-0.496)	0.20	(0.053-0.486)
Favia danae	0.30	(0.154-0.496)	0.13	(0.023-0.416)
Astreopora randalli	0.13	(0.044-0.297)	0.40	(0.175-0.671)
Pavona varians	0.23	(0.106-0.427)	0.13	(0.023-0.416)
Goniastrea edwardsi	0.00	(0.000-0.141)	0.53	(0.274-0.777)
Favia pallida	0.07	(0.012-0.235)	0.27	(0.089-0.552)
Cyphastrea serralia	0.17	(0.063-0.355)	0.00	(0.004-0.340)
Favia stelligera	0.07	(0.012-0.235)	0.20	(0.053-0.486)
Cyphastrea microphthalma	0.00	(0.000-0.141)	0.20	(0.053-0.486)
Favia matthai	0.10	(0.026-0.256)	0.00	(0.004-0.340)
Favites russelli	0.10	(0.026-0.256)	0.00	(0.004-0.340)
Galaxea fasicularis	0.03	(0.006-0.191)	0.13	(0.023-0.416)
Goniastrea retiformis	0.00	(0.000-0.141)	0.20	(0.053-0.486)
Pocillopora elegans	0.00	(0.000-0.141)	0.20	(0.053-0.486)
Porites vaughani	0.10	(0.026-0.256)	0.00	(0.004-0.340)
Favia sp.	0.07	(0.012-0.235)	0.00	(0.004-0.340)
Goniopora minor	0.07	(0.012-0.235)	0.00	(0.004-0.340)
Montipora nodosa	0.03	(0.006-0.191)	0.07	(0.004-0.340)
Acanthastrea brevis	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Acropora cophodactyla	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Acropora cuneata	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Favia favus	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Favia helianthoides	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Favia speciosa	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Millepora platyphyllia	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Montastrea colemani	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Montipora foveolata	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Oulophyllia crispa	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Platygyra pini	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Pocillopora damicornis	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Porites cf. *lobata*	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Stylocoeniella armata	0.03	(0.006-0.191)	0.00	(0.004-0.340)
Turbinarea stellata	0.03	(0.006-0.191)	0.00	(0.004-0.340)

Table S8. Proportion of quadrats containing each algae species at the near-vent and control sites. Species are ordered according to their overall prevalence at both sites. Those marked with an asterisk are considered calcifying.

Species	Near-vent		Control	
Cyanobacteria spp.	1	(0.859-1.000)	0.7333	(0.448-0.911)
*Jania capillacea**	0.77	(0.573-0.894)	1.00	(0.747-1.000)
Crustose coralline algae*	0.77	(0.573-0.894)	0.80	(0.514-0.947)
Dictyosphaeria intermedia	0.67	(0.471-0.821)	0.47	(0.223-0.726)
Tolypiocladia glomerulata	0.57	(0.377-0.740)	0.07	(0.004-0.340)
Caulerpa filicoides	0.53	(0.346-0.712)	0.00	(0.000-0.254)
Dictyota friabilis	0.30	(0.154-0.496)	0.40	(0.175-0.671)
*Amphiroa fragilissima**	0.30	(0.154-0.496)	0.20	(0.053-0.486)
*Neomeris annulata**	0.03	(0.006-0.191)	0.73	(0.448-0.911)
Peyssonnelia sp. A*	0.17	(0.063-0.355)	0.33	(0.130-0.613)
Gelidiales sp.	0.10	(0.026-0.256)	0.47	(0.223-0.726)
Dictyosphaeria versluysii	0.20	(0.084-0.391)	0.20	(0.053-0.486)
Cladophoropsis sp.	0.13	(0.044-0.297)	0.27	(0.089-0.552)
Falkenbergia sp.	0.20	(0.084-0.391)	0.13	(0.023-0.416)
Dictyosphaeria cavernosa	0.23	(0.106-0.427)	0.00	(0.000-0.254)
Peyssonnelia sp. B*	0.07	(0.012-0.235)	0.33	(0.130-0.613)
Ventricaria ventricosa	0.20	(0.084-0.391)	0.07	(0.004-0.340)
Phormidium crosbyanum	0.10	(0.026-0.256)	0.07	(0.004-0.340)
Cladophora sp.	0.03	(0.006-0.191)	0.13	(0.023-0.416)
Distromium flabellatum	0.00	(0.000-0.141)	0.20	(0.053-0.486)
*Padina minor**	0.00	(0.000-0.141)	0.20	(0.053-0.486)
Spatoglossum stipitatum	0.10	(0.026-0.256)	0.00	(0.000-0.254)
Caulerpa racemosa	0.07	(0.012-0.235)	0.00	(0.000-0.254)
Caulerpa webbiana	0.07	(0.012-0.235)	0.00	(0.000-0.254)
Champia sp.	0.00	(0.000-0.141)	0.13	(0.023-0.416)
Chondria sp.	0.00	(0.000-0.141)	0.13	(0.023-0.416)
Lyngbya sp.	0.03	(0.006-0.191)	0.07	(0.004-0.340)
Polysiphonia sp.	0.07	(0.012-0.235)	0.00	(0.000-0.254)
*Rhipidosiphon javensis**	0.07	(0.012-0.235)	0.00	(0.000-0.254)
Symploca hydnoides	0.07	(0.012-0.235)	0.00	(0.000-0.254)
Acanthophora pacifica	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Acetabularia sp.*	0.03	(0.006-0.191)	0.00	(0.000-0.254)
Asparagopsis taxiformis	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Bryopsis hypnoides	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Ceram dichotomous	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Chlorodesmis fastigiata	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Diatoms	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Dictyota ceylanica	0.00	(0.000-0.141)	0.07	(0.004-0.340)
Halimeda sp.*	0.03	(0.006-0.191)	0.00	(0.000-0.254)