

Supplementary Information

Title: Limited phosphorus availability is the Achilles' heel of tropical reef corals in a warming ocean

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Supplementary Table S1. Determination of Symbiodinium clade via BLASTn

Chloroplast Partial 23S rRNA gene	Host organism	Identity (%)	Site (bp)	E value
<i>Symbiodinium</i> Clade C1	<i>P.cactus</i>	100	623	0.0
	<i>T.reniformis</i>	99	599	0.0
	<i>P.damicornis</i>	99	623	0.0
	<i>G.fascicularis</i>	99	621	0.0
<i>Symbiodinium</i> Clade D1	<i>H.fuscescens</i>	99	718	0.0

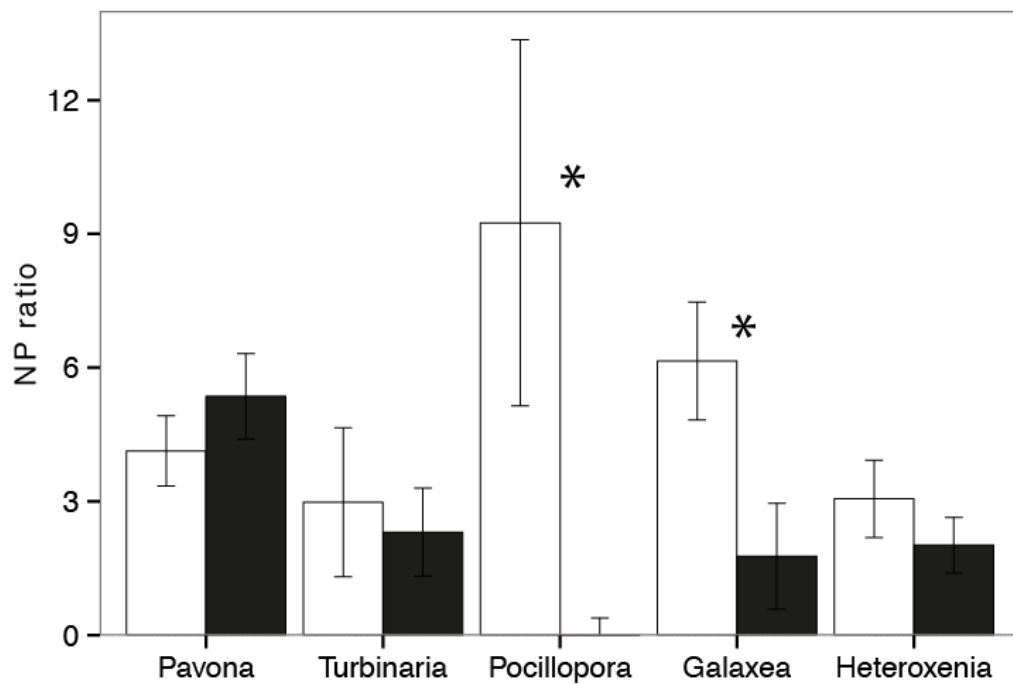
Supplementary Table S2. Nutrient uptakes normalized by zooxanthellae density

The uptake of nutrients (NH₄, NO₃ and PO₄; μmol of Nutrient (Nb Zoox)⁻¹ h⁻¹) normalized by the density of zooxanthellae according to the different coral species and the temperature steps (25°C and 30°C). Significant differences due to temperature were highlighted by an asterisk(*)

Species	Temperature	NH ₄ uptake	STDEV	NO ₃ uptake	STDEV	PO ₄ uptake	STDEV
<i>P.cactus</i>	T25	2.84E-08	1.58E-08	*2.23E-07	8.53E-08	7.1E-08	3.54E-08
	T30	5.19E-08	1.68E-08	1.04E-07	2.07E-08	4.93E-08	1.56E-08
<i>H.fuscescens</i>	T25	4.45E-08	1.77E-08	1.24E-07	1.76E-07	*2.9E-08	5.72E-09
	T30	1.21E-07	5.06E-08	1.22E-07	4.48E-08	1.32E-07	7.57E-08
<i>T.reniformis</i>	T25	8.99E-08	4.88E-08	3.04E-07	1.93E-07	*1.01E-08	5.02E-09
	T30	8.72E-08	2.44E-08	9.01E-08	3.36E-08	7.1E-08	1.85E-08
<i>P.danicornis</i>	T25	1.09E-07	3.04E-08	9.66E-08	2.25E-08	*3.65E-08	9.39E-09
	T30	1.05E-07	3.69E-08	1.52E-07	7.12E-08	1.84E-09	1.29E-09
<i>G.fascicularis</i>	T25	3.92E-08	2.75E-08	1.45E-07	4.84E-08	*2.01E-08	6.54E-09
	T30	4.25E-08	2.22E-08	9.71E-08	1.51E-08	4.11E-08	6.54E-09

Supplementary Figure S3. N-uptake: P-uptake

Ratio of total nitrogen (NH_4+NO_3) uptake on phosphorus uptake that have been previously normalized by $\mu\text{mol of N (mg prot)}^{-1} \text{ h}^{-1}$, according to the different coral species and the temperature steps. Significant effects of temperature were highlighted by an asterisk (*). Temperature steps (T25°C and T30°C) are represented by white and black bars, respectively.



Supplementary Table S4. Uptake of inorganic nutrients by *H.fuscescens*

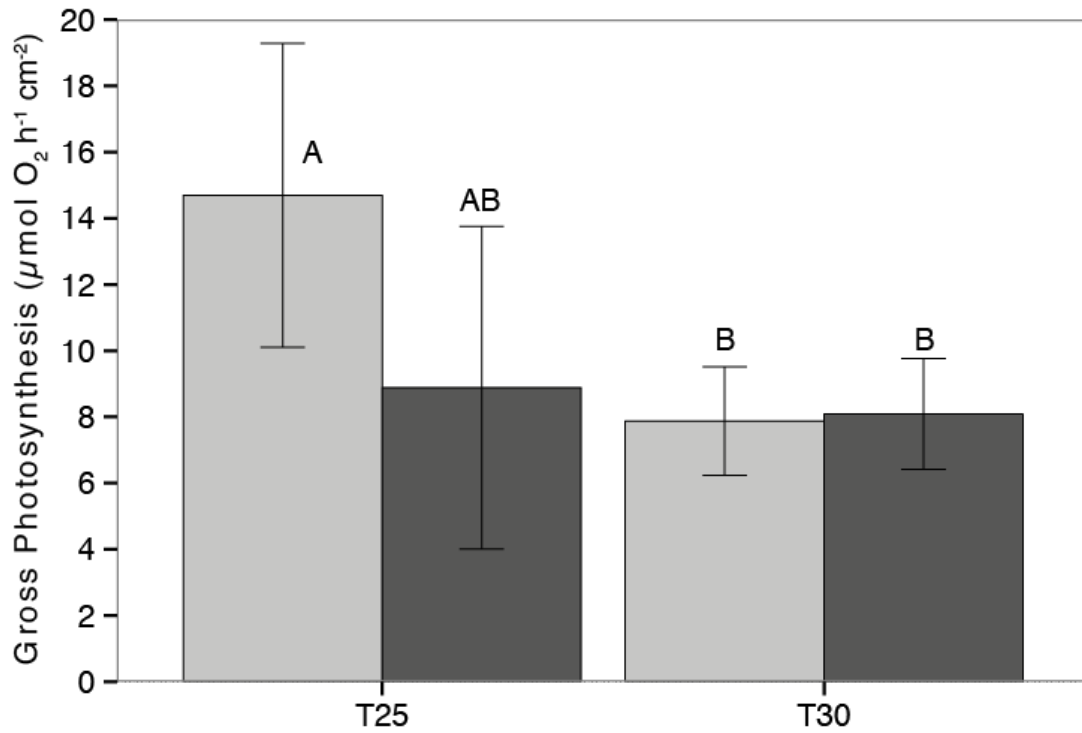
Uptake of inorganic nutrients (NH₄, NO₃, PO₄)

in μmol of nutrients (mg prot)- 1mn^{-1} . Significant effects of clove oil solution in decreasing polyp pulsation were highlighted by an asterisk (*).

Treatment	Mean	STDEV
NH ₄	0.023383	0.006532
NH ₄ EO	0.010009*	0.001504
NO ₃	0.010998	0.00374
NO ₃ EO	0.005465*	0.001504
PO ₄	0.000471	0.000104
PO ₄ EO	0.0003	8.96E-05

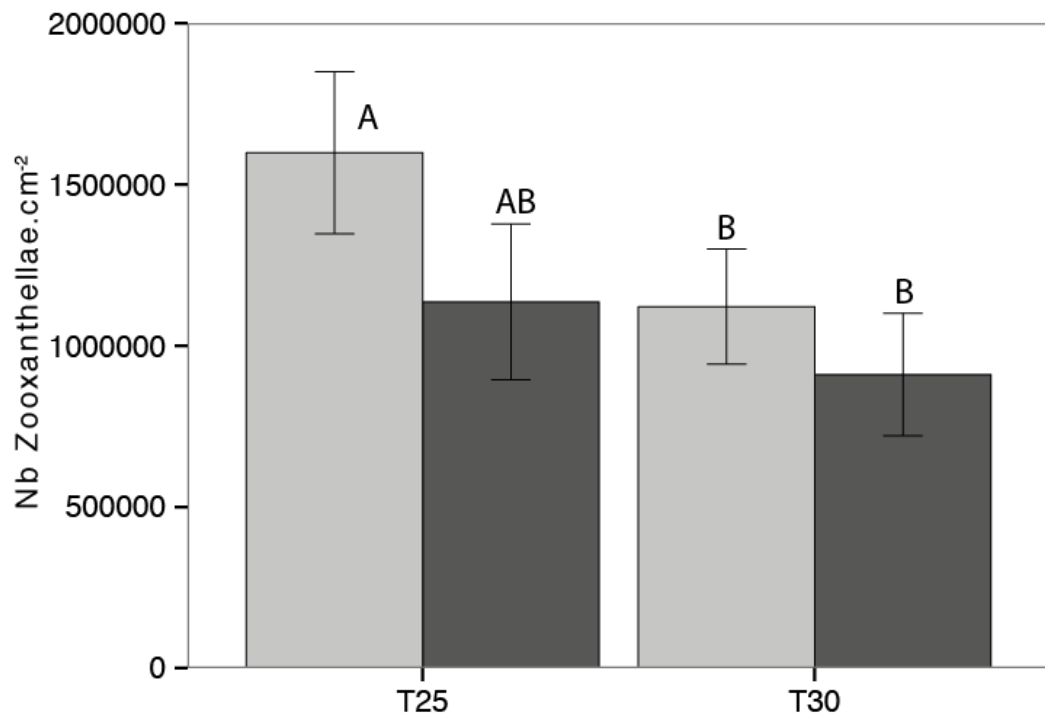
Supplementary Figure S5. Gross photosynthesis of *P.damicornis*

Rates of gross photosynthesis ($\mu\text{g C cm}^{-2} \text{ h}^{-1}$) of *P.damicornis* according to the nutrient treatment and the temperature steps (25°C and 30°C) relative to the second experiment. Control and P-enriched treatments are represented by grey and dark grey bars, respectively.



Supplementary Figure S6. Zooxanthellae density of *P.damicornis*

Density of zooxanthellae (Nb. Zooxanthellae cm⁻²) of *P.damicornis* according to the different nutrient treatment and the temperature steps (25°C and 30°C), relative to the second experiment. Control and P-enriched treatments are represented by grey and dark grey bars, respectively.



Supplementary Table 7. Summary of ANOVAs testing the effect of temperature (25°C, 30°C) and species or treatment (only) on the main physiological parameters. P values are considered significant for $p < 0.05$.

Source of variation	Df	F	p
<i>Protein content (hard corals)</i> (mg prot cm ⁻²)			
Species	3	19.29	< 0.0001
Temperature	1	0.11	0.746
Species x Temperature	3	3.13	0.04
<i>Chlorophyll content</i> (µg Chl(a+c) [*] (mg prot) ⁻¹)			
Species	4	45.8	< 0.0001
Temperature	1	116.2	< 0.0001
Species x Temperature	4	2.1	0.0106
<i>Zooxanthellae density</i> (Nb zooxanthellae mg prot) ⁻¹)			
Species	4	10.76	0.003
Temperature	1	17.51	< 0.0001
Species x Temperature	4	4.29	0.008
<i>Net Photosynthesis</i> (µmol O ₂ (mg prot) ⁻¹)			
Species	4	54.94	< 0.0001
Temperature	1	10.6	0.003
Species x Temperature	4	8.95	< 0.0001
<i>Respiration</i> (µmol O ₂ (mg prot) ⁻¹)			
Species	4	34.88	< 0.0001
Temperature	1	1.71	0.201
Species x Temperature	4	4.54	0.005
<i>Gross Photosynthesis</i> (µmol O ₂ (mg prot) ⁻¹)			
Species	4	30.86	< 0.0001
Temperature	1	5.44	0.026
Species x Temperature	4	10.99	< 0.0001

Supplementary Table 8. Summary of ANOVAs testing the effect of temperature (25°C, 30°C) and species or treatment (only) on the main physiological parameters. P values are considered significant for $p < 0.05$.

Source of variation	Df	F	p
<i>Ammonium uptake rate</i> ($\mu\text{mol NH}_4 \text{ h}^{-1} \text{ mg prot}^{-1}$)			
Species	4	12.22	<0.0001
Temperature	1	0.91	0.347
Species x Temperature	4	4.24	0.008
<i>Nitrate uptake rate</i> ($\mu\text{mol NH}_4 \text{ h}^{-1} \text{ mg prot}^{-1}$)			
Species	4	7.46	<0.0001
Temperature	1	15.9	<0.0001
Species x Temperature	4	10.32	<0.0001
<i>Phosphorus uptake rate</i> ($\mu\text{mol PO}_4 \text{ h}^{-1} \text{ mg prot}^{-1}$)			
Species	4	22.46	<0.0001
Temperature	1	51.38	<0.0001
Species x Temperature	4	20.07	<0.0001
<i>Ammonium uptake rate</i> ($\mu\text{mol NH}_4 \text{ h}^{-1} \text{ Nb Zoox}^{-1}$)			
Species	4	8.109	<0.0001
Temperature	1	4.201	0.05
Species x Temperature	4	2.270	0.083
<i>Nitrate uptake rate</i> ($\mu\text{mol NO}_3 \text{ h}^{-1} \text{ Nb Zoox}^{-1}$)			
Species	4	1.011	0.419
Temperature	1	4.702	0.039
Species x Temperature	4	2.552	0.062
<i>Phosphorus uptake rate</i> ($\mu\text{mol PO}_4 \text{ h}^{-1} \text{ Nb Zoox}^{-1}$)			
Species	4	5.387	0.002
Temperature	1	7.44	0.011
Species x Temperature	4	7.489	<0.0001
<i>NP ratio</i>			
Species	4	3.9	0.013
Temperature	1	32.31	0.0001
Species x Temperature	4	12.16	0.0001
<i>Ammonium uptake rate at 25°C (H.fuscescens)</i> ($\mu\text{mol NH}_4 \text{ mn}^{-1} \text{ mg prot}^{-1}$)			
Treatment	1	14.36	0.009
<i>Nitrate uptake rate at 25°C (H.fuscescens)</i> ($\mu\text{mol NO}_3 \text{ mn}^{-1} \text{ mg prot}^{-1}$)			
Treatment	1	7.538	0.033
<i>Phosphorus uptake rate at 25°C (H.fuscescens)</i> ($\mu\text{mol PO}_4 \text{ mn}^{-1} \text{ mg prot}^{-1}$)			
Treatment	1	2.214	0.197

Supplementary Table 9. Summary of ANOVAs testing the effect of temperature (25°C, 30°C) and nutritional treatment on the different physiological parameters for the second experiment. P values are considered significant for $p < 0.05$.

Source of variation	Df	F	p
<i>Gross photosynthesis</i> ($\mu\text{g C h}^{-1} \text{cm}^{-2}$)			
Temperature	1	6.845	0.019
Treatment	1	1.451	0.247
Temperature x Treatment	1	1.804	0.199
<i>Zooxanthellae density</i> (Nb Zoox cm^{-2})			
Temperature	1	6.701	0.018
Treatment	1	1.721	0.204
Temperature x Treatment	1	6.676	0.018
<i>Symbiont respiration rate, R_s</i> ($\mu\text{g C cm}^{-2} \text{h}^{-1}$)			
Temperature	1	0.51	0.484
Treatment	1	31.7	<0.0001
Temperature x Treatment	1	1.23	0.282
<i>Host Respiration rate, R_H</i> (%)			
Temperature	1	4.15	0.057
Treatment	1	13.68	0.002
Temperature x Treatment	1	0.18	0.673
<i>Calcification rate, C_c</i> ($\mu\text{g C cm}^{-2} \text{h}^{-1}$)			
Temperature	1	0.005	0.943
Treatment	1	1.238	0.292
Temperature x Treatment	1	<0.000	0.984
<i>rETR_{max}</i>			
Temperature	1	0.58	0.468
Treatment	1	9.051	0.017
Temperature x Treatment	1	5.589	0.046
<i>NPQ_{max}</i>			
Temperature	1	26	0.001
Treatment	1	13.68	0.002
Temperature x Treatment	1	0.74	0.416

Supplementary Table S10. Summary of factorial ANOVAs testing the effect of temperature (25°C, 30°C), nutritional treatment as well as the symbiotic compartment on the rates of carbon assimilation and transfer

<i>Carbon assimilated after 24h</i> ($\mu\text{g C h}^{-1}\text{cm}^{-2}$)			
Compartment	1	43.79	<0.0001
Temperature	1	11.24	0.002
Treatment	1	1.62	0.212
Compartment x Temperature	1	2.18	0.15
Compartment x Treatment	1	27.16	<0.0001
Temperature x Treatment	1	1.6	0.216
Compartment x Temperature x Treatment	1	3.29	0.08
<i>Carbon remaining within the symbiosis after 24h</i> (%)			
Compartment	1	51.18	<0.0001
Temperature	1	0.88	0.357
Treatment	1	1.12	0.3
Compartment x Temperature	1	25.43	<0.0001
Compartment x Treatment	1	1.42	0.243
Temperature x Treatment	1	0.37	0.548
Compartment x Temperature x Treatment	1	2.37	0.135
<i>Rate of photosynthates transferred after 24h</i> ($\mu\text{g C h}^{-1}\text{cm}^{-2}$)			
Temperature	1	26.5	<0.0001
Treatment	1	2.88	0.109
Temperature x Treatment	1	21.58	<0.0001
<i>Rate of photosynthates transferred after 24h</i> (%)			
Temperature	1	1.604	0.225
Treatment	1	9.648	0.007
Compartment x Treatment	1	3.24	0.092