1 Table S1. Measured dissolved inorganic carbon (DIC) and total alkalinity (TA), and

2 calculated $p\text{CO}_2$ (mean $\pm$ SD) at the end of the experiments in the cultures of

3 *Emiliania huxleyi*. Outliers in the data of $p\text{CO}_2$ were excluded in the table.

Treatment			DIC (μmol kg^{-1})	TA (μmol kg^{-1})	$p\text{CO}_2$ (μatm)
12 ℃	Low CO$_2$	N:P=10:1	1302 $\pm$93	1269 $\pm$99	1509 $\pm$61
		N:P=24:1	1328 $\pm$30	1292 $\pm$47	1564 $\pm$259
		N:P=63:1	1374 $\pm$43	1349 $\pm$42	1412 $\pm$36
	High CO$_2$	N:P=10:1	1956 $\pm$80	1962 $\pm$86	1357 $\pm$24
		N:P=24:1	2042 $\pm$29	2053 $\pm$29	1357 $\pm$132
		N:P=63:1	1829 $\pm$39	1801 $\pm$84	1041 $\pm$270
18 ℃	Low CO$_2$	N:P=10:1	763 $\pm$26	793 $\pm$7	552 $\pm$205
		N:P=24:1	885 $\pm$11	922 $\pm$20	567 $\pm$146
		N:P=63:1	1065 $\pm$5	1108 $\pm$13	633 $\pm$75
	High CO$_2$	N:P=10:1	1415 $\pm$267	1454 $\pm$209	1113 $\pm$848
		N:P=24:1	1278 $\pm$22	1196 $\pm$31	2944 $\pm$572
		N:P=63:1	1613 $\pm$61	1620 $\pm$56	1507 $\pm$574
24 ℃	Low CO$_2$	N:P=10:1	785 $\pm$22	808 $\pm$18	845 $\pm$443
		N:P=24:1	809 $\pm$18	682 $\pm$20	-
		N:P=63:1	1243 $\pm$27	1231 $\pm$17	1734 $\pm$281
	High CO$_2$	N:P=10:1	1266 $\pm$38	1240 $\pm$34	2079 $\pm$703
		N:P=24:1	1596 $\pm$89	1691 $\pm$62	1163 $\pm$269
		N:P=63:1	1616 $\pm$46	1550 $\pm$59	3295 $\pm$296

4   Table S2. Results of Akaike information criterion corrected (AICc) in GLMMs for

5   C:N:P stoichiometry, PIC and POC contents and their ratios, and fatty acid

6   proportions and contents in response to temperature, N:P supply ratios and pCO$_2$ in

7   *Emiliania huxleyi*. The selected models are shown in bold. TFAs: total fatty acids;

8   SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs:

9   polyunsaturated fatty acids; DHA: docosahexaenoic acid (22:6n-3).

Response variable	Effect builder	AICc
N:C biomass ratio (mol mol^{-1})	Main, two way and three way	-149.224
	Main, two way	-182.347
	Main	**-259.881**
P:C biomass ratio (mmol mol^{-1})	Main, two way and three way	230.956
	Main, two way	206.978
	Main	**155.039**
N:P biomass ratio (mol mol^{-1})	Main, two way and three way	362.508
	Main, two way	359.671
	Main	**356.018**
PIC (pg cell^{-1})	Main, two way and three way	285.804
	Main, two way	**284.025**
	Main	299.364
PIC (µg ml^{-1})	Main, two way and three way	300.200
	Main, two way	276.029
	Main	**231.545**
PIC production (pg cell^{-1} d^{-1})	Main, two way and three way	92.222
	Main, two way	64.188
	Main	**9.065**
POC (pg cell^{-1})	Main, two way and three way	336.081

	Main, two way	**333.586**
	Main	339.852
POC (μg ml^{-1})	Main, two way and three way	304.408
	Main, two way	280.234
	Main	**235.488**
POC production (pg cell^{-1} d^{-1})	Main, two way and three way	88.022
	Main, two way	59.365
	Main	**5.219**
PIC/POC	Main, two way and three way	56.147
	Main, two way	26.690
	Main	**-36.148**
SFA proportion (% of TFAs)	Main, two way and three way	304.845
	Main, two way	**302.115**
	Main	304.984
MUFA proportion (% of TFAs)	Main, two way and three way	300.697
	Main, two way	278.543
	Main	**264.319**
PUFA proportion (% of TFAs)	Main, two way and three way	359.132
	Main, two way	336.555
	Main	**318.057**
DHA proportion (% of TFAs)	Main, two way and three way	304.197
	Main, two way	**301.625**
	Main	310.200
TFA content (μg mg^{-1} C^{-1})	Main, two way and three way	554.949
	Main, two way	536.499
	Main	**512.664**
SFA content (μg mg^{-1} C^{-1})	Main, two way and three way	437.382
	Main, two way	416.262

	Main	**393.592**
MUFA content (μg mg^{-1} C^{-1})	Main, two way and three way	421.162
	Main, two way	400.009
	Main	**374.298**
PUFA content (μg mg^{-1} C^{-1})	Main, two way and three way	485.817
	Main, two way	465.876
	Main	**432.787**
DHA content (μg mg^{-1} C^{-1})	Main, two way and three way	449.256
	Main, two way	428.583
	Main	**391.542**

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37 Table S3. The nature (synergism or antagonism) and magnitude (the difference

38 between observed combined effect and predicted additive effect) of the observed

39 interactive effects of warming, N and P deficiency (-N and -P), and enhanced pCO$_2$

40 (HCO$_2$) on PIC and POC cellular contents, saturated fatty acid proportion (SFA

41 proportion), and docosahexaenoic acid (DHA) proportion in *Emiliania huxleyi*.

Variable	Treatment	Interaction		
		Nature	Magnitude $\pm$ SE	n
PIC (pg cell^{-1})	Warming $\times$ -N	Antagonism	-2.010 $\pm$ 0.524	12
	Warming $\times$ -P	Synergism	9.511 $\pm$ 2.264	12
	Warming $\times$ HCO$_2$	Synergism	17.640 $\pm$ 1.495	18
POC (pg cell^{-1})	Warming $\times$ -N	Synergism	19.056 $\pm$ 0.392	12
	Warming $\times$ -P	Synergism	39.644 $\pm$ 2.854	12
SFA proportion (% of TFAs)	-N $\times$ HCO$_2$	Synergism	28.746 $\pm$ 1.070	9
	-P $\times$ HCO$_2$	Synergism	24.096 $\pm$ 0.840	9
DHA proportion (% of TFAs)	Warming $\times$ -N	Synergism	4.622 $\pm$ 0.873	12
	Warming $\times$ -P	Synergism	4.316 $\pm$ 0.671	12
	Warming $\times$ HCO$_2$	Synergism	5.013 $\pm$ 0.912	18

43 Table S4. Fatty acid profiles of *Emiliania huxleyi* under three temperature (12, 18 and 24 ℃), three N:P supply ratios (10:1, 24:1 and 63:1 mol

44 mol^{-1}) and two pCO$_2$ levels (560 and 2400 μatm). Data are expressed as fatty acid contents (mean ± SD) (μg · mg C^{-1}) and percentages of total

45 fatty acids (% of TFAs). SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; TFAs, total fatty

46 acids.

	12 ℃											
	Low pCO$_2$						High pCO$_2$					
	N:P=10:1		N:P=24:1		N:P=63:1		N:P=10:1		N:P=24:1		N:P=63:1	
	Content	%	Content	%	Content	%	Content	%	Content	%	Content	%
14:0	31 ±1	19 ±2	26 ±7	20 ±1	23 ±5	16 ±2	22 ±1	17 ±2	24 ±2	20 ±3	12 ±0	15 ±0
16:0	11 ±1	7 ±0	10 ±3	7 ±0	9 ±3	6 ±1	11 ±3	8 ±1	9 ±3	8 ±1	4 ±0	5 ±0
16:1n-7	1 ±0	1 ±0	1 ±0	1 ±0	2 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
18:0	3 ±0.1	2 ±0	4 ±2	3 ±0	6 ±3	4 ±1	6 ±4	4 ±2	4 ±3	3 ±2	2 ±0	2 ±0
18:1n-9	33 ±1	20 ±0	27 ±7	20 ±1	25 ±5	17 ±2	23 ±2	18 ±1	22 ±4	19 ±1	11 ±0	13 ±0
18:1n-7	6 ±0	3 ±0	5 ±1	4 ±0	7 ±1	5 ±0	5 ±0	4 ±0	5 ±1	4 ±0	4 ±0	4 ±0
18:2n-6	9 ±1	5 ±0	7 ±2	6 ±0	5 ±1	4 ±0	5 ±1	4 ±0	5 ±1	5 ±0	2 ±0	3 ±0
18:3n-6	0 ±0	0 ±0	0 ±0	0 ±0	0.1 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
18:3n-3	11 ±1	7 ±0	8 ±2	6 ±0	10 ±3	7 ±0	9 ±1	7 ±0	7 ±1	6 ±1	6 ±0	7 ±0
18:4n-3	7 ±1	4 ±0	5 ±2	4 ±0	6 ±2	4 ±0	6 ±1	4 ±0	5 ±1	4 ±0	4 ±0.3	5 ±0
20:2n-6	0 ±0	0 ±0	0 ±0	0 ±0	1 ±0	1 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	1 ±0
20:3n-6	0.4 ±0	0 ±0	0.6 ±0	0 ±0	1 ±0	1 ±0	0 ±0	0 ±0	1 ±1	1 ±1	0 ±0	0 ±0
22:0	1 ±0	1 ±0	1 ±1	1 ±0	2 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	0 ±0	1 ±0

20:5n-3	2 ±0	1 ±0	1 ±0	1 ±0	2 ±1	1 ±0	1 ±1	1 ±0	1 ±1	1 ±0	1 ±0	1 ±0
23:0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	1 ±1	1 ±1	0 ±0	0 ±0	0 ±0	0 ±0
24:0	1 ±0	0 ±0	0 ±0	0 ±0	1 ±1	0 ±0	1 ±1	1 ±0	0 ±0	0 ±0	0 ±0	0 ±0
22:5n-3, 24:1n-9	1 ±0	1 ±0	1 ±0	1 ±0	2 ±1	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
22:6n-3	29 ±4	18 ±1	23 ±8	17 ±1	33 ±12	22 ±3	26 ±5	20 ±1	20 ±4	17 ±1	22 ±1	27 ±1
Unidentified	14 ±2	9 ±1	10 ±3	7 ±0	12 ±5	8 ±1	10 ±2	7 ±0	9 ±1	7 ±1	10 ±1	12 ±1
$\sum$SFAs[a]	47 ±0	29 ±2	43 ±12	32 ±1	41 ±10	28 ±2	41 ±8	32 ±2	38 ±8	32 ±2	20 ±1	24 ±1
$\sum$MUFAs[b]	41 ±2	26 ±0	35 ±9	26 ±1	35 ±7	25 ±2	30 ±3	23 ±2	30 ±7	25 ±1	16 ±0.3	20 ±0
$\sum$PUFAs[c]	59 ±6	37 ±2	47 ±15	35 ±1	58 ±19	39 ±3	49 ±8	38 ±2	41 ±9	35 ±2	36 ±2	44 ±1
$\sum$TFAs[d]	162 ±9		134 ±38		146 ±42		130 ±20		118 ±25		82 ±3	

[a] also includes 20:0 present at < 0.5% of TFAs in all treatments. [b] also includes 14:1, 20:1n-9 and 22:1n-9 present at < 0.5% of TFAs in all treatments. [c] also includes 16:3n-4, 20:4n-6, 20:3n-3, 20:4n-3, 22:2n-6 present at < 0.5% of TFAs in all treatments. [d] also includes the unidentified FA component.

	18 ℃											
	Low pCO$_2$						High pCO$_2$					
	N:P=10:1		N:P=24:1		N:P=63:1		N:P=10:1		N:P=24:1		N:P=63:1	
	Content	%	Content	%	Content	%	Content	%	Content	%	Content	%
14:0	27 ±4	18 ±1	17 ±1	17 ±0	21 ±1	15 ±1	32 ±5	18 ±1	20 ±5	18 ±2	16 ±1	16 ±1
16:0	9 ±1	6 ±0	5 ±0	5 ±0	7 ±0	5 ±0	12 ±2	7 ±0	8 ±3	7 ±1	6 ±0	6 ±0
16:1n-7	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
18:0	2 ±0	2 ±0	1 ±0	1 ±0	2 ±0	2 ±0	3 ±0	2 ±0	3 ±2	3 ±1	2 ±1	2 ±1
18:1n-9	23 ±2	15 ±0	12 ±0	13 ±0	16 ±1	11 ±0	31 ±3	17 ±1	17 ±4	16 ±1	15 ±0	15 ±0
18:1n-7	6 ±0	4 ±0	3 ±0	3 ±0	6 ±0	4 ±0	6 ±0	4 ±0	4 ±1	4 ±0	4 ±0	4 ±0
18:2n-6	4 ±0	3 ±0	3 ±0	3 ±0	3 ±0	2 ±0	5 ±0	3 ±0	4 ±1	4 ±0	3 ±0	2 ±0
18:3n-6	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
18:3n-3	10 ±1	7 ±0	8 ±0	8 ±0	10 ±1	7 ±0	12 ±1	7 ±0	7 ±2	6 ±0	8 ±0	8 ±0
18:4n-3	10 ±1	7 ±0	8 ±0	8 ±0	10 ±0	7 ±0	10 ±1	6 ±0	7 ±3	6 ±1	6 ±0	6 ±0
20:2n-6	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	1 ±0	1 ±0
20:3n-6	0 ±0	0 ±0	0 ±0	0 ±0	1 ±0	0 ±0	0 ±0	0 ±0	1 ±1	1 ±0	0 ±0	0 ±0
22:0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
20:5n-3	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±1	1 ±0	1 ±0	1 ±0
23:0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
24:0	1 ±0	0 ±0	1 ±0	1 ±0	0 ±0	0 ±0	1 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
22:5n-3, 24:1n-9	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	2 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
22:6n-3	40 ±3	26 ±2	25 ±2	26 ±1	40 ±5	29 ±2	42 ±2	25 ±2	25 ±9	23 ±3	27 ±2	26 ±2
Unidentified	13 ±1	9 ±1	11 ±0	11 ±0	16 ±1	12 ±0	13 ±1	8 ±0	9 ±3	8 ±1	10 ±1	10 ±1

$\sum$SFAs[a]	41 ±4	27 ±2	24 ±1	25 ±0	32 ±1	23 ±1	49 ±7	28 ±2	33 ±9	29 ±6	26 ±2	25 ±2
$\sum$MUFAs[b]	32 ±2	21 ±0	17 ±1	18 ±0	25 ±1	18 ±0	40 ±4	23 ±1	24 ±6	22 ±2	22 ±0	22 ±0
$\sum$PUFAs[c]	67 ±4	44 ±2	45 ±2	47 ±0	67 ±6	48 ±1	73 ±0	42 ±3	46 ±16	41 ±4	45 ±2	44 ±2
$\sum$TFAs[d]	153 ±10		97 ±5		140 ±9		176 ±11		112 ±34		103 ±1	

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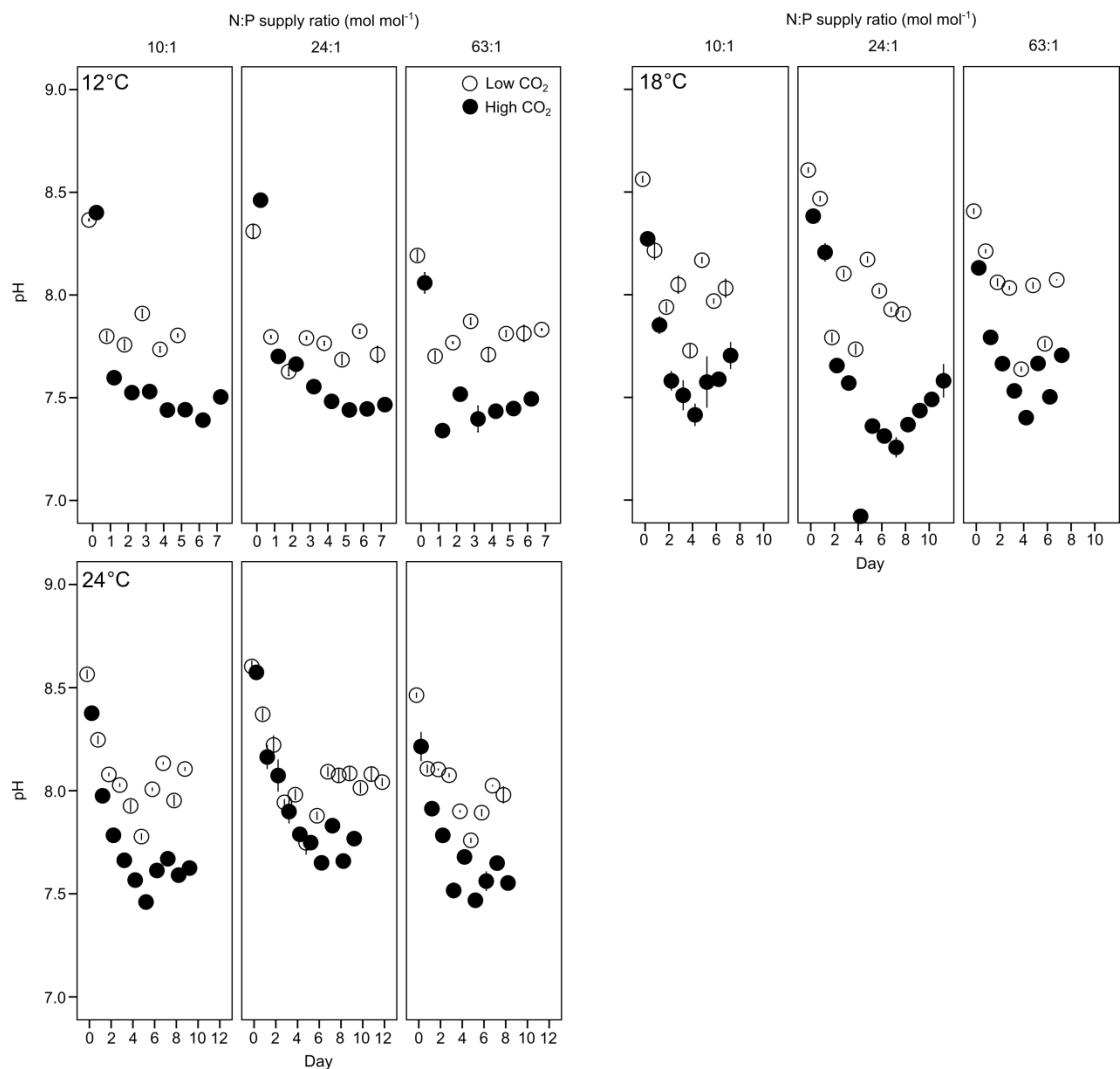

	24 °C											
	Low pCO$_2$						High pCO$_2$					
	N:P=10:1		N:P=24:1		N:P=63:1		N:P=10:1		N:P=24:1		N:P=63:1	
	Content	%	Content	%	Content	%	Content	%	Content	%	Content	%
14:0	17 ±1	17 ±1	15 ±1	18 ±2	23 ±5	18 ±1	18 ±0	19 ±2	7 ±3	16 ±1	12 ±1	14 ±1
16:0	7 ±0	7 ±0	6 ±1	7 ±1	10 ±1	8 ±1	8 ±0	8 ±1	4 ±1	10 ±1	7 ±1	8 ±0
16:1n-7	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
18:0	2 ±0	2 ±0	2 ±1	3 ±1	4 ±2	3 ±2	2 ±1	2 ±1	3 ±0	7 ±3	3 ±2	4 ±1
18:1n-9	11 ±0	11 ±0	7 ±1	8 ±1	11 ±2	8 ±0	12 ±1	13 ±1	5 ±2	11 ±1	8 ±0	10 ±1
18:1n-7	4 ±0	3 ±0	3 ±0	3 ±0	8 ±1	7 ±1	4 ±0	4 ±0	2 ±1	5 ±0	7 ±0	8 ±0
18:2n-6	3 ±0	3 ±0	4 ±1	5 ±0	5 ±1	4 ±0	3 ±0	3 ±0	2 ±1	4 ±0	3 ±0	4 ±0
18:3n-6	0 ±0	0 ±0	1 ±0	1 ±0	1 ±0	0 ±0	0 ±0	0 ±0	1 ±0	2 ±2	0 ±0	0 ±0
18:3n-3	6 ±0	6 ±0	4 ±1	6 ±0	6 ±1	5 ±0	5 ±1	5 ±0	2 ±1	4 ±1	4 ±0	5 ±0
18:4n-3	10 ±1	10 ±1	10 ±2	12 ±1	11 ±2	9 ±0	8 ±1	9 ±1	4 ±2	8 ±1	7 ±1	8 ±1
20:2n-6	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
20:3n-6	0 ±0	0 ±0	1 ±1	1 ±1	1 ±0	1 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0
22:0	1 ±0	1 ±0	0 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	2 ±2	1 ±0	1 ±0
20:5n-3	1 ±0	1 ±0	0 ±0	0 ±0	1 ±1	1 ±0	1 ±0	1 ±0	1 ±1	2 ±1	0 ±0	1 ±0
23:0	0 ±0	0 ±0	1 ±1	1 ±1	0 ±0	0 ±0	0 ±0	1 ±0	1 ±0	2 ±1	0 ±0	0 ±0
24:0	0 ±0	0 ±0	1 ±1	1 ±1	1 ±0	1 ±0	0 ±0	0 ±0	1 ±0	2 ±1	1 ±0	1 ±0
22:5n-3, 24:1n-9	1 ±0	1 ±0	0 ±0	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0	0 ±0	0 ±0	1 ±0	1 ±0
22:6n-3	30 ±1	30 ±1	21 ±3	26 ±1	31 ±8	25 ±2	23 ±7	25 ±4	8 ±5	17 ±5	21 ±1	25 ±1
Unidentified	6 ±0	6 ±0	4 ±0	5 ±0	9 ±2	7 ±0	5 ±1	5 ±1	2 ±1	4 ±1	6 ±1	7 ±0

$\sum$SFAs[a]	27 ±1	27 ±0	25 ±4	30 ±2	39 ±6	31 ±4	30 ±1	32 ±4	16 ±3	39 ±7	24 ±4	29 ±1
$\sum$MUFAs[b]	16 ±0	16 ±0	11 ±1	13 ±1	21 ±4	17 ±1	17 ±1	19 ±1	8 ±4	18 ±2	17 ±1	21 ±1
$\sum$PUFAs[c]	51 ±2	51 ±1	42 ±7	51 ±2	56 ±12	45 ±3	41 ±9	44 ±4	17 ±9	39 ±5	36 ±3	43 ±0
$\sum$TFAs[d]	100 ±2		81 ±12		125 ±21		93 ±11		42 ±16		82 ±8	

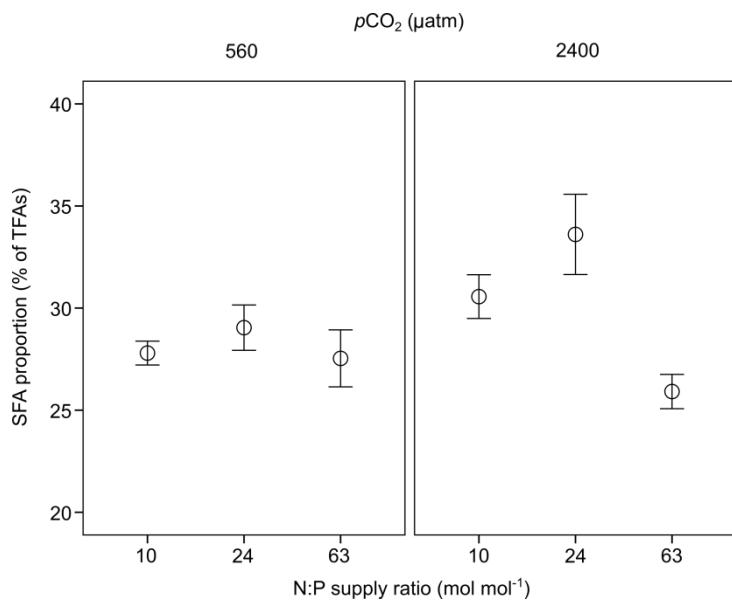
Table S5. Results of the selected GLMMs testing for the effects of temperature, N:P supply ratios and $p\mathrm{CO_2}$ on fatty acid contents in *Emiliania huxleyi*. Significant p values are shown in bold. T: temperature; N:P: N:P supply ratio; TFA: total fatty acid; SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; DHA: docosahexaenoic acid (22:6n-3).

Variable	Factor	Coefficienct $\pm$ SE	t	p
TFA content (μg mg^{-1} C^{-1})	Intercept	202.099 $\pm$ 17.745	11.389	<0.001
	T	-3.444 $\pm$ 0.827	-4.164	**<0.001**
	$p\mathrm{CO_2}$	-0.014 $\pm$ 0.004	-3.038	**0.004**
	N:P	-0.188 $\pm$ 0.182	-1.033	0.307
SFA content (μg mg^{-1} C^{-1})	Intercept	58.540 $\pm$ 5.265	11.119	<0.001
	T	-0.978 $\pm$ 0.245	-3.986	**<0.001**
	$p\mathrm{CO_2}$	-0.003 $\pm$ 0.001	-2.240	**0.030**
	N:P	-0.118 $\pm$ 0.054	-2.182	**0.034**
MUFA content (μg mg^{-1} C^{-1})	Intercept	53.910 $\pm$ 4.324	12.468	<0.001
	T	-1.361 $\pm$ 0.202	-6.755	**<0.001**
	$p\mathrm{CO_2}$	-0.002 $\pm$ 0.001	-1.882	0.066
	N:P	-0.074 $\pm$ 0.044	-1.675	0.100
PUFA content (μg mg^{-1} C^{-1})	Intercept	71.361 $\pm$ 7.854	9.086	<0.001
	T	-0.664 $\pm$ 0.366	-1.813	0.076
	$p\mathrm{CO_2}$	-0.007 $\pm$ 0.002	-3.626	**0.001**
	N:P	-0.024 $\pm$ 0.081	-0.292	0.772
DHA content (μg mg^{-1} C^{-1})	Intercept	36.201 $\pm$ 5.156	7.021	<0.001
	T	-0.248 $\pm$ 0.240	-1.031	0.308
	$p\mathrm{CO_2}$	-0.004 $\pm$ 0.001	-3.034	**0.004**
	N:P	0.021 $\pm$ 0.053	0.392	0.697

Fig. S1 Time course of pH (mean ± SE) under three temperature, three N:P supply ratios and two target pCO$_2$ levels (low CO$_2$: 560 µatm; high CO$_2$: 2400µatm) in the semi-continuous cultures of *E. huxleyi*.

Fig. S2

Fig. S2 Responses of the proportion of saturated fatty acids (SFAs) to N:P supply

ratios and pCO$_2$ in *E. huxleyi*.