

Supplementary information for “Active modulation of the calcifying fluid carbonate chemistry ($\delta^{11}\text{B}$, B/Ca) and seasonally invariant coral calcification at sub-tropical limits”

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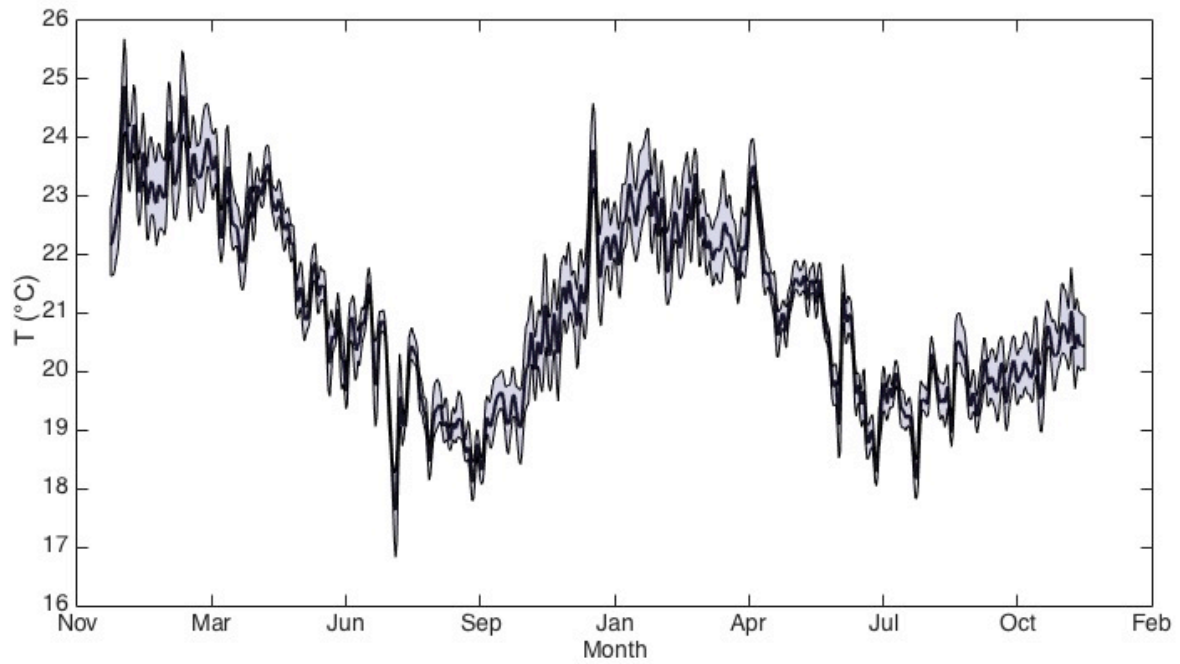
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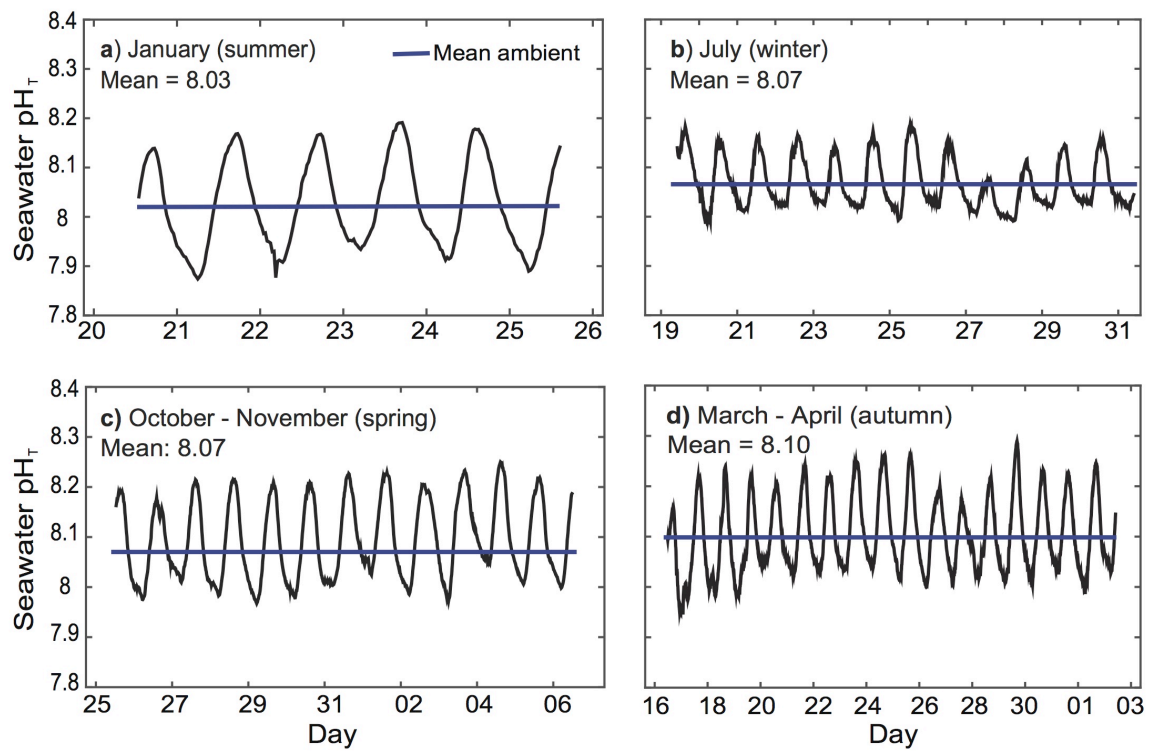
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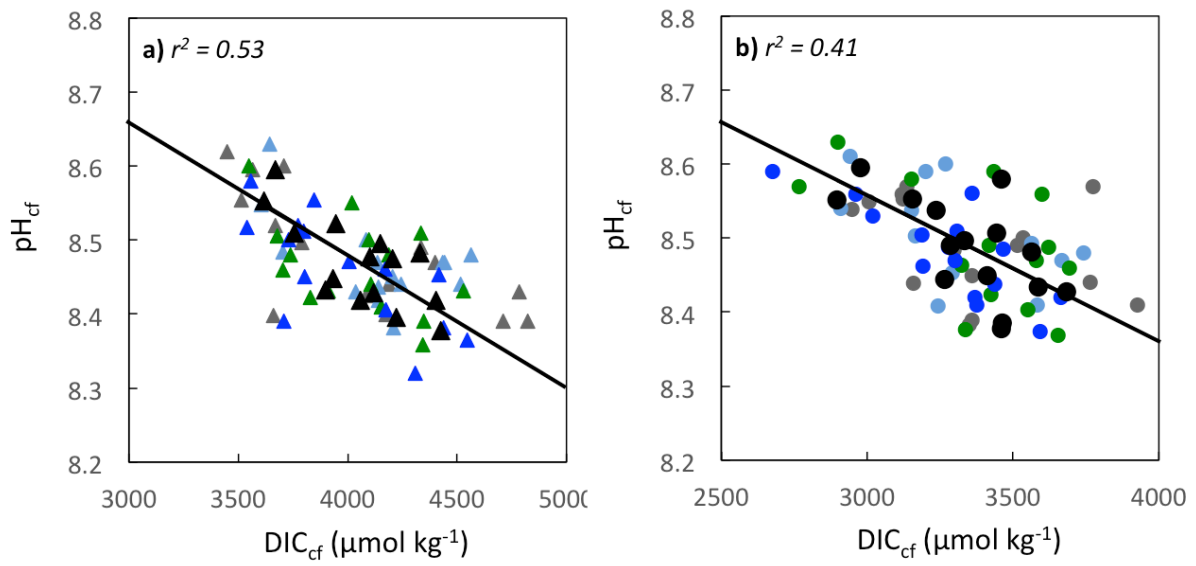


Supplementary Figure S1. Seasonal changes in seawater temperature at Rottnest Island.

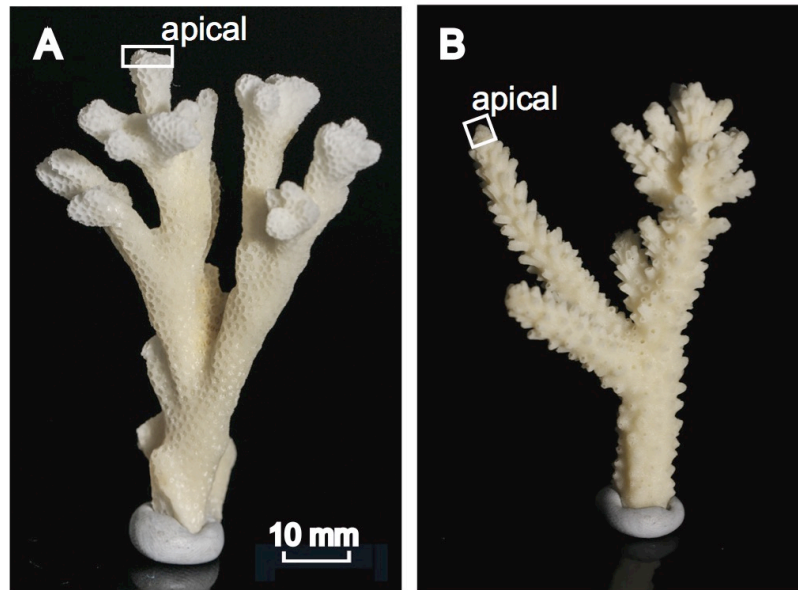
Daily averaged water temperature at Salmon Bay, Rottnest Island from December 2012 through December 2014. The heavy black line shows the average daily temperatures while the grey regions represent the range between hourly minimum and maximum temperatures for each day.



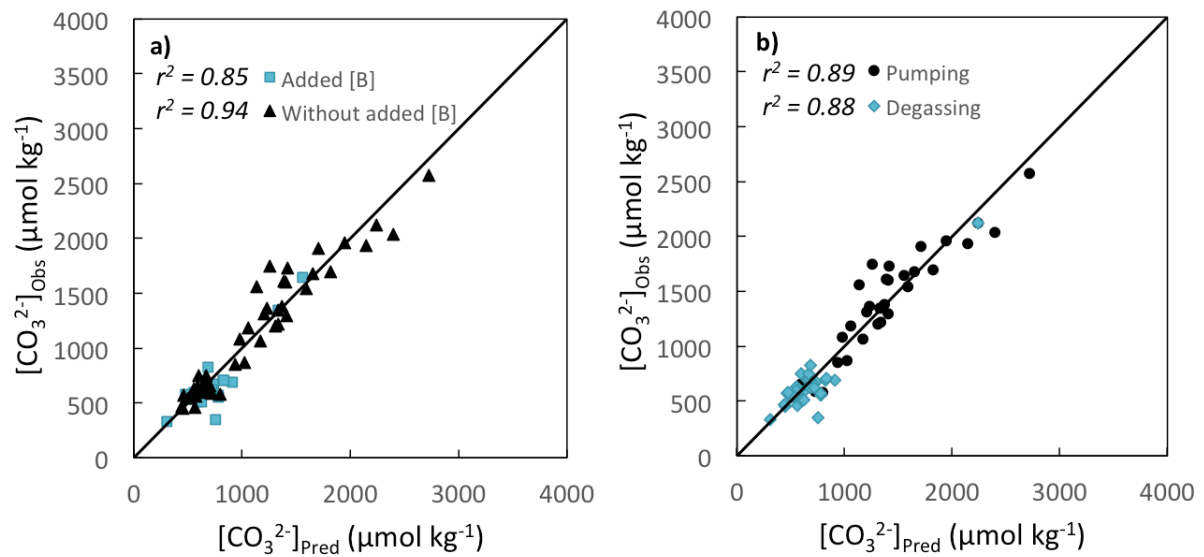
Supplementary Figure S2. Seasonal seawater pH_T at Rottneest Island. Diurnal variations of seawater pH_T at Salmon Bay, Rottneest Island taken during (a) 20th–25th of January 2014³⁶, (b) 19th–30th of July 2014, (c) 25th Oct–6th Nov 2014 and (d) 16th Mar–1st April 2015. The solid blue lines denote the average pH_T over the period of deployment.



Supplementary Figure S3. Inverse relationships between seasonal pH_{cf} versus DIC_{cf}. Coral pH_{cf} plotted against DIC_{cf} for (a) *Acropora yongei* (pH_{cf} = -0.0002 DIC_{cf} + 9.17) and (b) *Pocillopora damicornis* (pH_{cf} = -0.0002 DIC_{cf} + 9.21). Coloured symbols represent each colony while the black symbols denote the mean ± 1 SE ($n = 4$; colony 1 = grey, colony 2 = light blue, colony 3 = green, colony 4 = dark blue) for each time point.



Supplementary Figure S4. Region sampled for geochemical measurements. Sampling schematic showing the apical location sampled for (a) *Pocillopora damicornis*, and (b) *Acropora yongei* (photographs taken by C. Ross).



Supplementary Figure S5. Relationships between predicted $[\text{CO}_3^{2-}]_{\text{pred}}$ (using Eq. 2)²¹ and measured $[\text{CO}_3^{2-}]_{\text{obs}}$ from inorganic experiments⁴⁵. Symbols are the means of different experiments; (a) with added B and without added B, and (b) pumping experiments and degassing experiments. Both plots show 1:1 regression line. The relationship between the predicted and observed⁴⁵ for all data combined is $[\text{CO}_3^{2-}]_{\text{obs}} = 0.97[\text{CO}_3^{2-}]_{\text{pred}} + 19.87$ (mean absolute error of $\pm 116 \mu\text{mol kg}^{-1}$; $r^2 = 0.93$, $n = 64$).

Supplementary Tables

Supplementary Table S1. Seasonal changes in environmental conditions at the study

site. Environmental data (mean \pm 1 SE) measured at Rottnest Island, Western Australia³⁶.

Variable	Units	Summer	Winter
Temperature	°C	23.0 \pm 0.2	19.5 \pm 0.2
Light	mol m ⁻² d ⁻¹	45.9 \pm 0.6	19.3 \pm 0.3
Total Alkalinity	μ mol kg ⁻¹	2,282 \pm 18	2,297 \pm 4
<i>p</i> CO ₂	μ atm	310 \pm 20	339 \pm 17
Carbonate	μ mol kg ⁻¹	248 \pm 9	211 \pm 8
DIC	μ mol kg ⁻¹	1928 \pm 20	1997 \pm 14
Ω_{sw}	-	3.89 \pm 0.14	3.28 \pm 0.12
Ammonium	mmol m ⁻³	0.50 \pm 0.03	0.43 \pm 0.06
Nitrate	mmol m ⁻³	0.25 \pm 0.04	0.77 \pm 0.08
Phosphate	mmol m ⁻³	0.03 \pm 0.01	0.19 \pm 0.04

Supplementary Table S2. Coral skeletal B/Ca, Li/Mg and Sr/Ca ratios, and $\delta^{11}\text{B}$ values.

The measurements of skeletal B/Ca, Li/Mg and Sr/Ca ratios and $\delta^{11}\text{B}$ values for *Acropora yongei* and *Pocillopora damicornis* (mean \pm 1 SE) at Rottneest Island, Western Australia.

Date	<i>A. yongei</i>							
	B/Ca	SE	Li/Mg	SE	Sr/Ca	SE	$\delta^{11}\text{B}$	SE
	mmol mol ⁻¹		mmol mol ⁻¹		mmol mol ⁻¹		‰	
Feb-13	0.51	0.07	1.84	0.01	9.46	0.03	22.36	0.40
Mar-13	0.54	0.19	1.90	0.01	9.58	0.02	23.04	0.41
Apr-13	0.52	0.28	1.95	0.02	9.57	0.01	23.35	0.17
Jun-13	0.54	0.25	1.97	0.03	9.68	0.03	23.79	0.42
Aug-13	0.58	0.16	2.12	0.03	9.79	0.04	25.18	0.29
Oct-13	0.52	0.06	2.04	0.03	9.63	0.03	22.85	0.06
Dec-13	0.50	0.23	1.81	0.02	9.51	0.02	23.35	0.31
Jan-14	0.49	0.26	1.80	0.03	9.50	0.03	22.58	0.38
Feb-14	0.49	0.12	1.85	0.02	9.63	0.01	21.98	0.16
Apr-14	0.56	0.18	1.96	0.02	9.58	0.03	22.76	0.18
Jul-14	0.59	0.08	2.05	0.06	9.76	0.05	24.08	0.25
Aug-14	0.58	0.06	2.20	0.02	9.69	0.01	23.37	0.22
Oct-14	0.53	0.23	2.08	0.02	9.74	0.04	23.16	0.55
Dec-14	0.54	0.11	2.05	0.02	9.66	0.01	22.16	0.06
Mar-15	0.52	0.03	1.92	0.03	9.56	0.02	22.57	0.29
Date	<i>P. damicornis</i>							
	B/Ca	SE	Li/Mg	SE	Sr/Ca	SE	$\delta^{11}\text{B}$	SE
	mmol mol ⁻¹		mmol mol ⁻¹		mmol mol ⁻¹		‰	
Feb-13	0.62	0.14	1.71	0.05	9.30	0.02	22.24	0.54
Mar-13	0.62	0.09	1.81	0.02	9.36	0.02	23.05	0.45
Apr-13	0.63	0.14	1.84	0.03	9.36	0.03	23.48	0.62
Jun-13	0.66	0.22	1.92	0.07	9.45	0.06	24.25	0.81
Aug-13	0.71	0.28	1.90	0.02	9.47	0.04	24.76	0.40
Oct-13	0.61	0.20	1.87	0.04	9.53	0.02	24.41	0.31
Dec-13	0.60	0.17	1.85	0.02	9.45	0.03	23.35	0.25
Jan-14	0.59	0.25	1.84	0.01	9.39	0.02	22.79	0.60
Feb-14	0.60	0.16	1.75	0.03	9.36	0.03	22.98	0.42
Apr-14	0.63	0.17	1.81	0.04	9.43	0.02	22.11	0.26
Jul-14	0.66	0.25	2.02	0.03	9.58	0.04	23.78	0.39
Aug-14	0.74	0.11	1.96	0.03	9.54	0.02	24.01	0.24
Oct-14	0.63	0.18	2.01	0.03	9.58	0.02	23.31	0.59
Dec-14	0.66	0.07	1.90	0.02	9.50	0.03	23.24	0.42
Mar-15	0.66	0.11	1.85	0.02	9.42	0.01	22.86	0.32

Supplementary Table S3. Coral carbonate ion concentrations $[\text{CO}_3^{2-}]_{\text{cf}}$ within the calcifying fluid. The $[\text{CO}_3^{2-}]_{\text{cf}}$ estimated from boron to calcium ratios (B/Ca) for *Acropora yongei* and *Pocillopora damicornis* (mean \pm 1 SE, $n = 4$) at Rottnest Island, Western Australia.

Date	<i>A. yongei</i>		<i>P. damicornis</i>	
	$[\text{CO}_3^{2-}]_{\text{cf}}$	SE	$[\text{CO}_3^{2-}]_{\text{cf}}$	SE
Feb-13	874.0	35.1	694.5	33.8
Mar-13	872.8	44.6	755.6	6.8
Apr-13	959.8	52.4	804.5	15.6
Jun-13	938.1	35.9	791.2	22.1
Aug-13	946.9	22.0	769.8	29.4
Oct-13	898.3	19.2	888.4	25.3
Dec-13	989.0	24.5	815.5	20.0
Jan-14	911.3	31.1	777.7	28.9
Feb-14	856.4	27.7	769.1	34.4
Apr-14	810.9	37.9	658.1	7.5
Jul-14	878.4	19.5	767.0	40.8
Aug-14	839.9	29.3	697.5	8.7
Oct-14	903.3	9.0	769.7	10.1
Dec-14	802.3	15.2	738.3	15.6
Mar-15	876.0	18.0	710.1	9.1

Supplementary Table S4. Seasonal changes in measured and modelled calcification rates for branching *Acropora yongei* and *Pocillopora damicornis* at Rottneest Island. Measured mean calcification rates¹ ($\text{mg cm}^{-2} \text{d}^{-1}$)³⁶ and predicted mean absolute calcification rates ($\text{mg cm}^{-2} \text{d}^{-1}$) using the three model scenarios. Scenario 1 are calcification rates modelled using inorganic rate kinetics using seasonally varying temperature and Ω_{cf} , scenario 2 are the rates estimated using the pH_{cf} values calculated from fixed condition experiments for *Acropora* spp., ($y = 0.51\text{pH}_{\text{sw}} + 4.28^{40,49}$; pH_{sw} ranged from 8.03–8.10), and scenario 3 are the estimated relative rates using a constant mean temperature (21.7°C) and seasonally varying Ω_{cf} . Light blue shading denotes winter and unshaded areas denote summer.

	Date	Growth Rates ($\text{mg cm}^{-2} \text{d}^{-1}$)			
		Measured	IpHRAC	pH_{cf} (fixed aquaria experiments)	Constant T°C, Variable Ω_{cf}
<i>Acropora yongei</i>	Feb-13	1.54	0.54	0.54	0.36
	Mar-13	1.46	0.49	0.44	0.38
	Apr-13	2.02	0.57	0.47	0.43
	Jun-13	1.76	0.42	0.32	0.46
	Aug-13	1.61	0.34	0.22	0.50
	Oct-13	1.66	0.35	0.30	0.45
	Dec-13	1.79	0.50	0.41	0.46
	Jan-14	1.67	0.50	0.45	0.41
	Feb-14	1.33	0.45	0.48	0.37
	Apr-14	1.25	0.40	0.36	0.39
<i>Pocillopora damicornis</i>	Feb-13	0.60	0.36	0.39	0.25
	Mar-13	0.47	0.39	0.35	0.31
	Apr-13	0.84	0.43	0.34	0.33
	Jun-13	0.77	0.33	0.23	0.36
	Aug-13	0.79	0.25	0.17	0.36
	Oct-13	0.90	0.34	0.23	0.44
	Dec-13	0.81	0.38	0.30	0.35
	Jan-14	0.54	0.38	0.33	0.32
	Feb-14	0.30	0.37	0.35	0.31
Apr-14	0.55	0.26	0.28	0.25	

Supplementary Table S5. Coral skeletal $\delta^{11}\text{B}$ values ($\pm 2\text{ SD}$). The individual measurements of skeletal $\delta^{11}\text{B}$ for *Acropora yongei* and *Pocillopora damicornis*.

Location / Species	Date Collected	$\delta^{11}\text{B}_{(\text{carb})}$ (permil)	Error ($\pm 2\text{s int}$)
Rottnest Island - <i>Acropora yongei</i>	03-Mar-13	23.02	0.04
Rottnest Island - <i>Acropora yongei</i>	03-Mar-13	22.83	0.05
Rottnest Island - <i>Acropora yongei</i>	03-Mar-13	22.35	0.04
Rottnest Island - <i>Acropora yongei</i>	03-Mar-13	21.25	0.07
Rottnest Island - <i>Acropora yongei</i>	05-Apr-13	24.14	0.05
Rottnest Island - <i>Acropora yongei</i>	05-Apr-13	22.88	0.04
Rottnest Island - <i>Acropora yongei</i>	05-Apr-13	22.96	0.05
Rottnest Island - <i>Acropora yongei</i>	05-Apr-13	22.18	0.06
Rottnest Island - <i>Acropora yongei</i>	06-May-13	23.02	0.05
Rottnest Island - <i>Acropora yongei</i>	06-May-13	23.30	0.05
Rottnest Island - <i>Acropora yongei</i>	06-May-13	23.24	0.05
Rottnest Island - <i>Acropora yongei</i>	06-May-13	23.84	0.06
Rottnest Island - <i>Acropora yongei</i>	20-Jun-13	25.00	0.04
Rottnest Island - <i>Acropora yongei</i>	20-Jun-13	23.04	0.06
Rottnest Island - <i>Acropora yongei</i>	20-Jun-13	23.46	0.04
Rottnest Island - <i>Acropora yongei</i>	20-Jun-13	23.68	0.10
Rottnest Island - <i>Acropora yongei</i>	21-Aug-13	25.18	0.04
Rottnest Island - <i>Acropora yongei</i>	21-Aug-13	25.28	0.04
Rottnest Island - <i>Acropora yongei</i>	21-Aug-13	24.06	0.04
Rottnest Island - <i>Acropora yongei</i>	21-Aug-13	26.20	0.06
Rottnest Island - <i>Acropora yongei</i>	15-Nov-13	22.97	0.05
Rottnest Island - <i>Acropora yongei</i>	15-Nov-13	22.74	0.04
Rottnest Island - <i>Acropora yongei</i>	15-Nov-13	22.96	0.06
Rottnest Island - <i>Acropora yongei</i>	15-Nov-13	22.74	0.10
Rottnest Island - <i>Acropora yongei</i>	23-Dec-13	22.54	0.04
Rottnest Island - <i>Acropora yongei</i>	23-Dec-13	23.21	0.05
Rottnest Island - <i>Acropora yongei</i>	23-Dec-13	23.77	0.04
Rottnest Island - <i>Acropora yongei</i>	23-Dec-13	23.90	0.06
Rottnest Island - <i>Acropora yongei</i>	17-Jan-14	22.22	0.05
Rottnest Island - <i>Acropora yongei</i>	17-Jan-14	23.04	0.04
Rottnest Island - <i>Acropora yongei</i>	17-Jan-14	23.37	0.06
Rottnest Island - <i>Acropora yongei</i>	17-Jan-14	21.69	0.11
Rottnest Island - <i>Acropora yongei</i>	27-Feb-14	22.38	0.05
Rottnest Island - <i>Acropora yongei</i>	27-Feb-14	21.96	0.06
Rottnest Island - <i>Acropora yongei</i>	27-Feb-14	21.62	0.06
Rottnest Island - <i>Acropora yongei</i>	27-Feb-14	21.96	0.06
Rottnest Island - <i>Acropora yongei</i>	14-May-14	22.25	0.06
Rottnest Island - <i>Acropora yongei</i>	14-May-14	23.06	0.04
Rottnest Island - <i>Acropora yongei</i>	14-May-14	22.74	0.06
Rottnest Island - <i>Acropora yongei</i>	14-May-14	22.98	0.03
Rottnest Island - <i>Acropora yongei</i>	18-Jul-14	24.12	0.06
Rottnest Island - <i>Acropora yongei</i>	18-Jul-14	23.93	0.06
Rottnest Island - <i>Acropora yongei</i>	18-Jul-14	24.73	0.13
Rottnest Island - <i>Acropora yongei</i>	18-Jul-14	23.54	0.05

Rottnest Island - <i>Acropora yongei</i>	02-Sep-14	23.11	0.06
Rottnest Island - <i>Acropora yongei</i>	02-Sep-14	22.99	0.06
Rottnest Island - <i>Acropora yongei</i>	02-Sep-14	23.38	0.07
Rottnest Island - <i>Acropora yongei</i>	02-Sep-14	23.98	0.12
Rottnest Island - <i>Acropora yongei</i>	24-Oct-14	24.69	0.06
Rottnest Island - <i>Acropora yongei</i>	24-Oct-14	23.22	0.05
Rottnest Island - <i>Acropora yongei</i>	24-Oct-14	22.20	0.04
Rottnest Island - <i>Acropora yongei</i>	24-Oct-14	22.52	0.06
Rottnest Island - <i>Acropora yongei</i>	19-Dec-14	22.27	0.05
Rottnest Island - <i>Acropora yongei</i>	19-Dec-14	22.17	0.07
Rottnest Island - <i>Acropora yongei</i>	19-Dec-14	22.23	0.07
Rottnest Island - <i>Acropora yongei</i>	19-Dec-14	21.99	0.06
Rottnest Island - <i>Acropora yongei</i>	31-Mar-15	21.91	0.12
Rottnest Island - <i>Acropora yongei</i>	31-Mar-15	22.64	0.16
Rottnest Island - <i>Acropora yongei</i>	31-Mar-15	22.45	0.14
Rottnest Island - <i>Acropora yongei</i>	31-Mar-15	23.29	0.15
Rottnest Island - <i>Pocillopora damicornis</i>	03-Mar-13	22.31	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	03-Mar-13	21.56	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	03-Mar-13	22.23	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	03-Mar-13	22.87	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	05-Apr-13	23.56	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	05-Apr-13	22.51	0.07
Rottnest Island - <i>Pocillopora damicornis</i>	05-Apr-13	23.25	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	05-Apr-13	22.87	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	06-May-13	24.36	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	06-May-13	23.45	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	06-May-13	23.07	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	06-May-13	23.04	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	20-Jun-13	23.27	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	20-Jun-13	25.08	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	20-Jun-13	24.73	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	20-Jun-13	23.94	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	21-Aug-13	24.40	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	21-Aug-13	24.59	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	21-Aug-13	25.33	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	21-Aug-13	24.72	0.07
Rottnest Island - <i>Pocillopora damicornis</i>	15-Nov-13	24.19	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	15-Nov-13	24.75	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	15-Nov-13	24.60	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	15-Nov-13	24.11	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	23-Dec-13	23.57	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	23-Dec-13	23.39	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	23-Dec-13	22.99	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	23-Dec-13	23.44	0.07
Rottnest Island - <i>Pocillopora damicornis</i>	17-Jan-14	22.53	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	17-Jan-14	22.42	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	17-Jan-14	23.69	0.03
Rottnest Island - <i>Pocillopora damicornis</i>	17-Jan-14	22.52	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	27-Feb-14	23.09	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	27-Feb-14	23.51	0.04

Rottnest Island - <i>Pocillopora damicornis</i>	27-Feb-14	22.53	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	27-Feb-14	22.79	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	14-May-14	22.12	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	14-May-14	22.39	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	14-May-14	21.82	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	14-May-14	21.88	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	18-Jul-14	24.01	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	18-Jul-14	23.83	0.04
Rottnest Island - <i>Pocillopora damicornis</i>	18-Jul-14	24.06	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	18-Jul-14	23.22	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	02-Sep-14	23.82	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	02-Sep-14	23.83	0.07
Rottnest Island - <i>Pocillopora damicornis</i>	02-Sep-14	24.34	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	02-Sep-14	24.04	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	24-Oct-14	24.20	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	24-Oct-14	23.02	0.05
Rottnest Island - <i>Pocillopora damicornis</i>	24-Oct-14	23.03	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	24-Oct-14	23.00	0.06
Rottnest Island - <i>Pocillopora damicornis</i>	19-Dec-14	22.63	0.10
Rottnest Island - <i>Pocillopora damicornis</i>	19-Dec-14	23.44	0.14
Rottnest Island - <i>Pocillopora damicornis</i>	19-Dec-14	23.36	0.18
Rottnest Island - <i>Pocillopora damicornis</i>	19-Dec-14	23.53	0.15
Rottnest Island - <i>Pocillopora damicornis</i>	31-Mar-15	22.91	0.15
Rottnest Island - <i>Pocillopora damicornis</i>	31-Mar-15	23.02	0.08
Rottnest Island - <i>Pocillopora damicornis</i>	31-Mar-15	22.40	0.11
Rottnest Island - <i>Pocillopora damicornis</i>	31-Mar-15	23.11	0.11