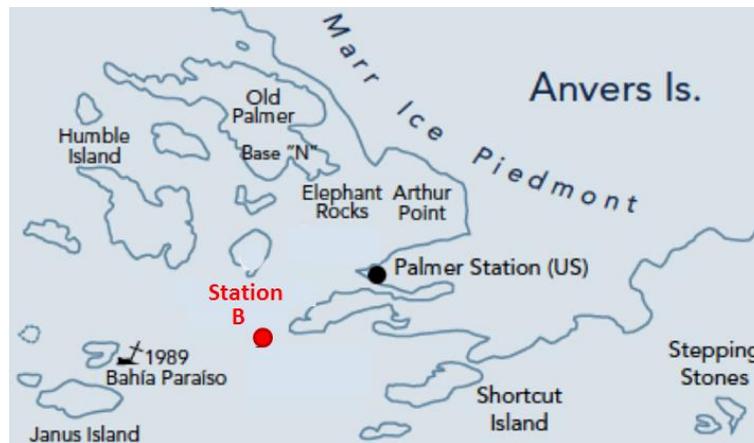


## ***New Phytologist* Supporting Information**

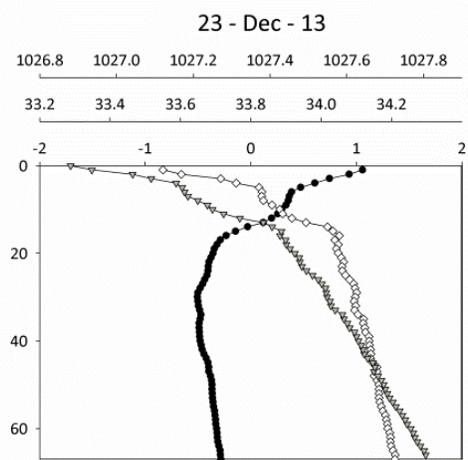
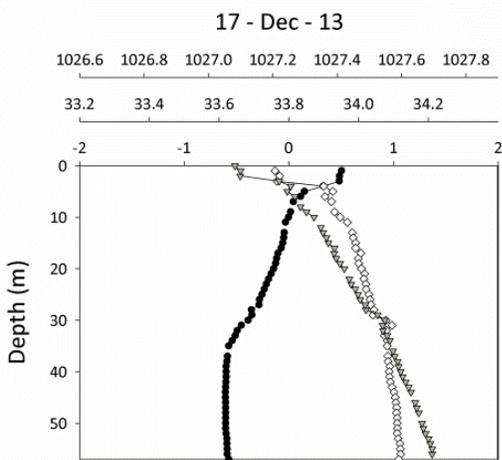
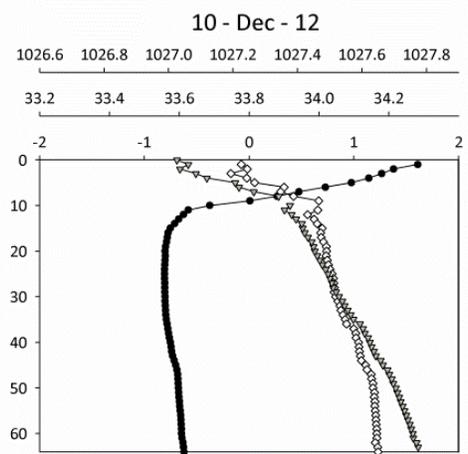
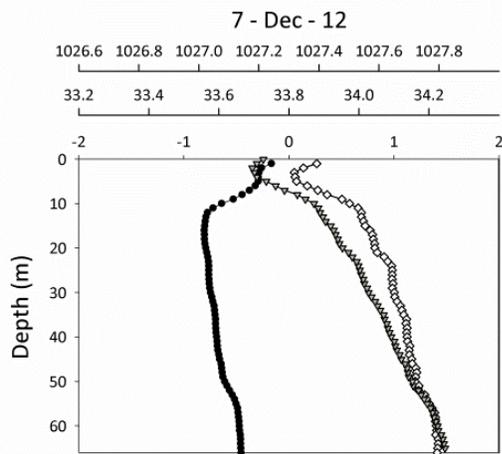
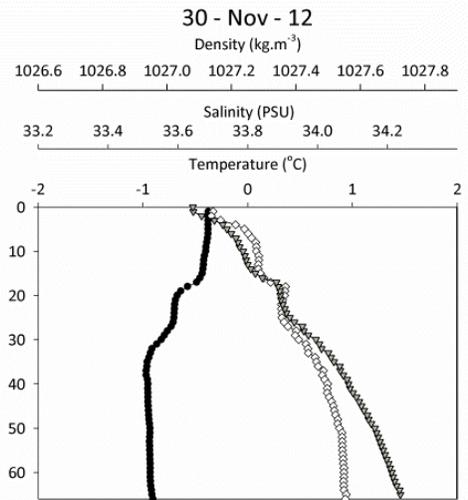
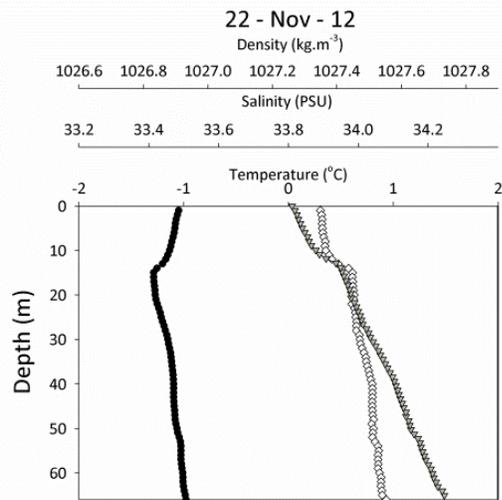
### **Gross and net production during the spring bloom in the Western Antarctic Peninsula**

Johanna A. L. Goldman, Sven A. Kranz, Jodi N. Young, Philippe D. Tortell, Rachel H. R. Stanley, Michael L. Bender and Francois M. M. Morel

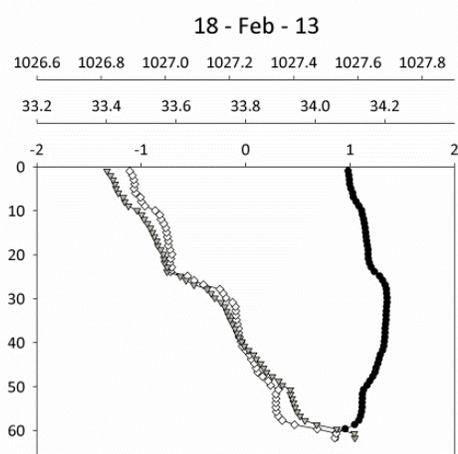
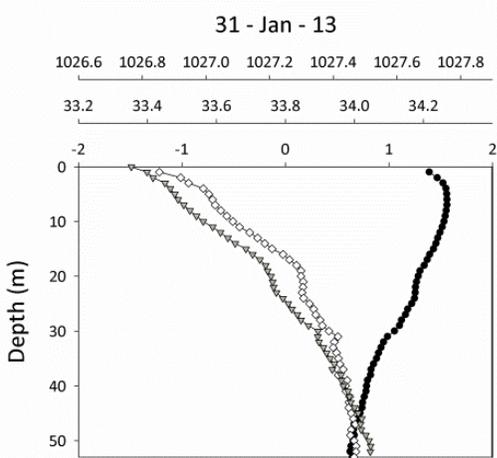
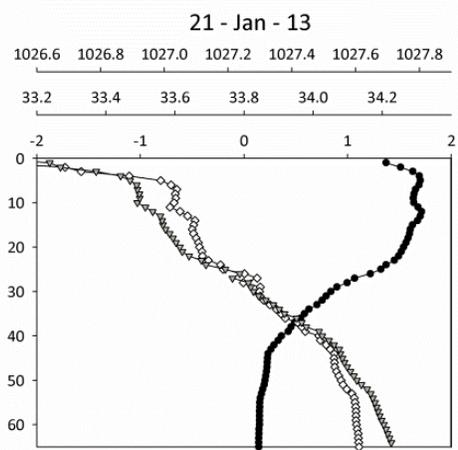
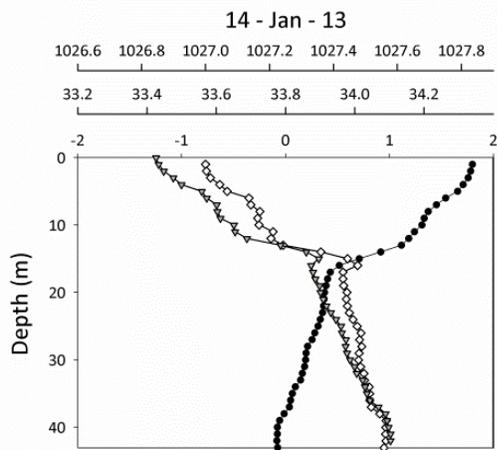
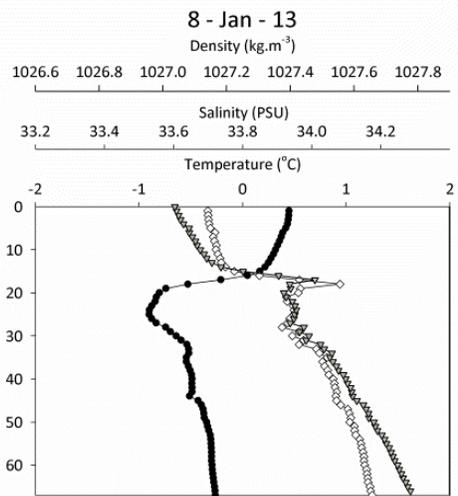
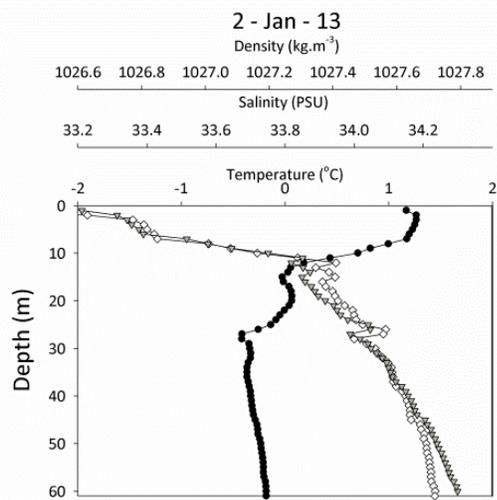
The following Supporting Information is available for this article:  
Figs S1–S6 and Notes S1–S4



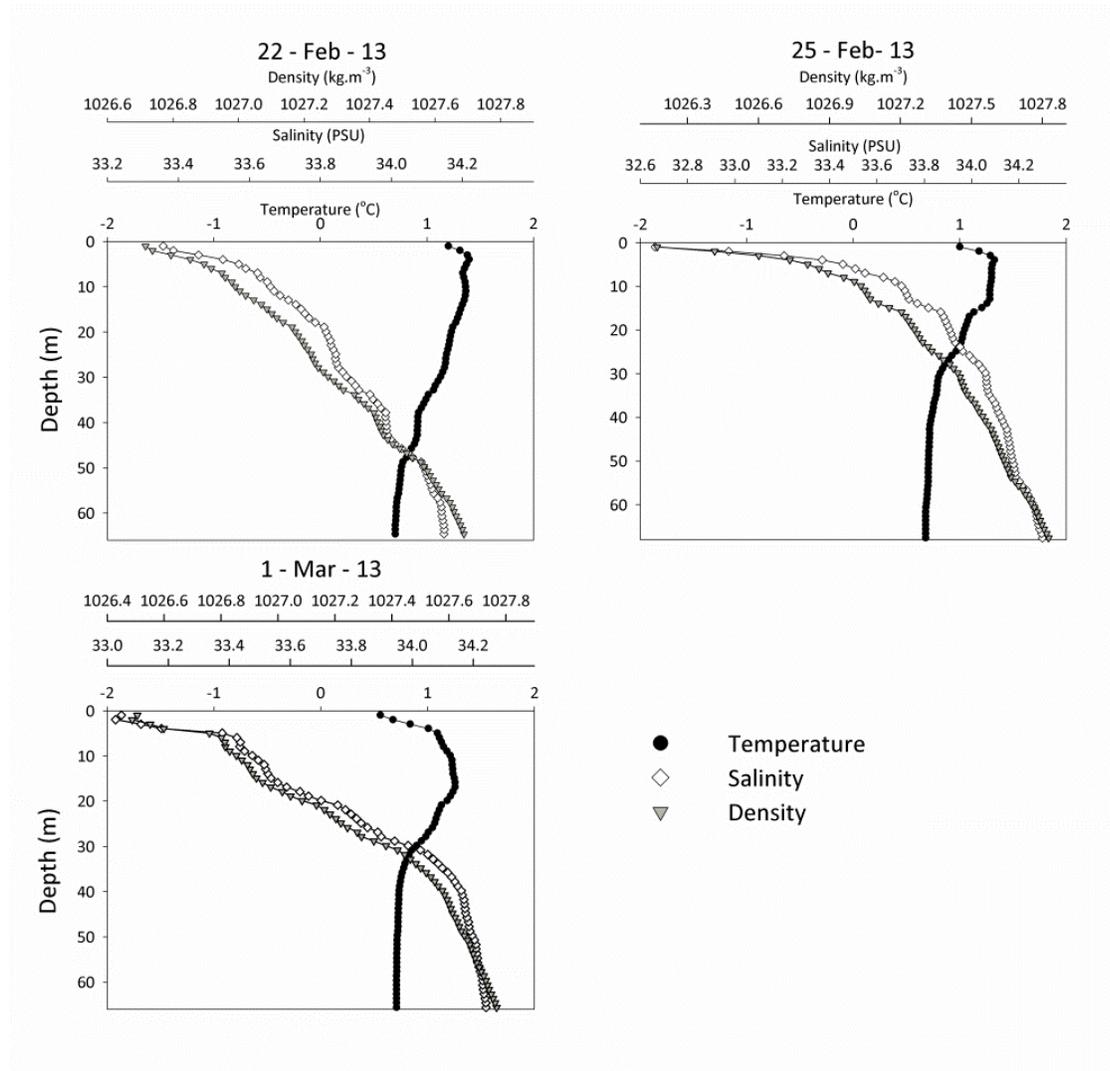
**Fig. S1** Map of the sampling region around Palmer station (credit: Secretariat of the Antarctic Treaty). PAL-LTER Station B is the station where all discrete samplings were performed in this study.



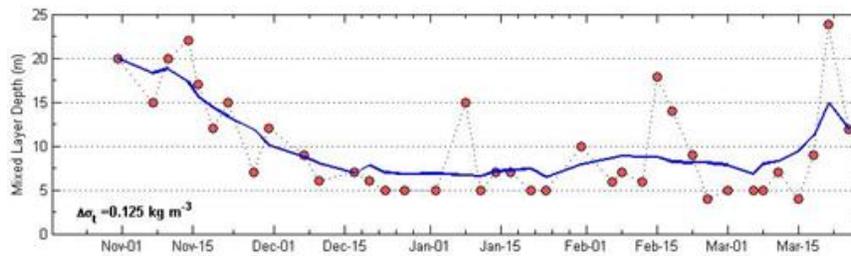
- Temperature
- ◇ Salinity
- ▽ Density



- Temperature
- ◇ Salinity
- ▽ Density

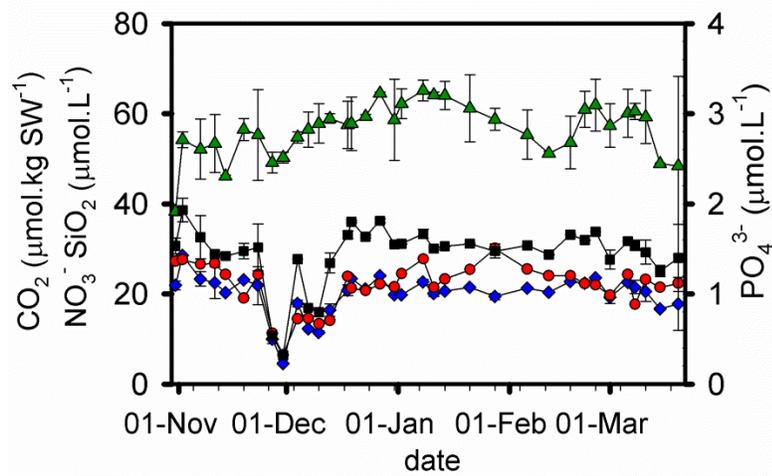


**Fig. S2** Depth profiles of Temperature (black circles), Salinity (white diamonds) and Density (grey triangles) at LTER-station B measured using a Seabird SBE 19plus Seacat Profiler.

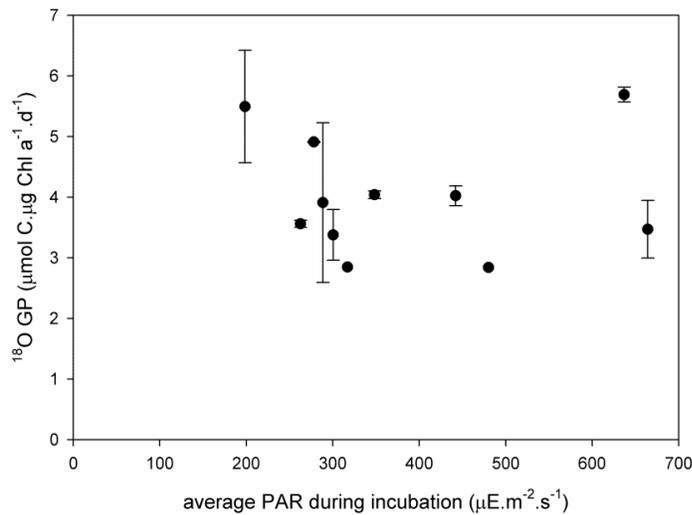


**Fig. S3** Mixed layer depth (MLD) throughout the season determined by

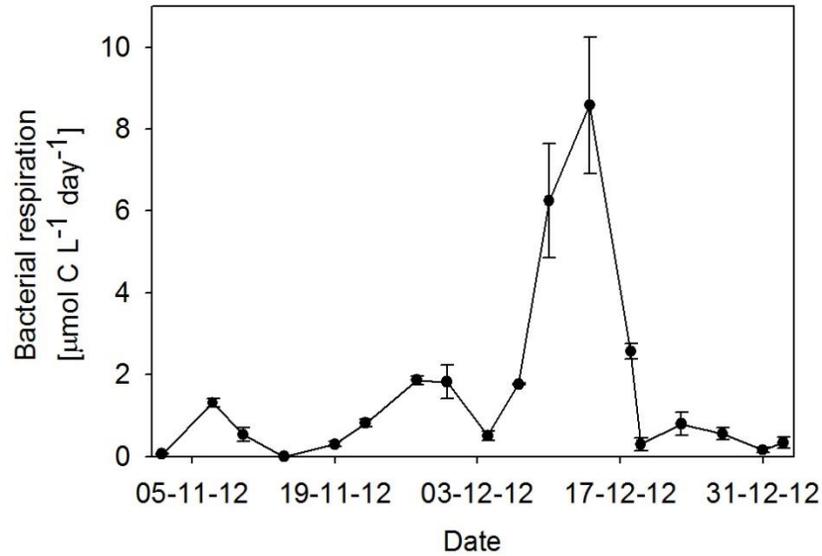
density profiles. Density was calculated from temperature and salinity data using the TEOS-10 seawater equation of state (<http://www.teos-10.org/software.htm>). MLD corresponds to density difference of  $0.125 \text{ kg m}^{-3}$  from surface values.



**Fig. S4** Concentrations of major nutrients throughout the season. Left axis:  $\text{CO}_2$  (red circle),  $\text{NO}_3^-$  (blue diamond) and  $\text{SiO}_2$  (green triangle). Right axis:  $\text{PO}_4^{3-}$  (black square). Error bars for  $\text{NO}_3^-$ ,  $\text{SiO}_2$  and  $\text{PO}_4^{3-}$  represent standard deviation of duplicate measurements.



**Fig. S5** Chlorophyll *a* normalized gross photosynthesis (as measured in  $^{18}\text{O}$  incubations) versus the average PAR during the incubation. The absence of effect of PAR on GP indicates light saturation without photoinhibition. Error bars represent standard deviation of duplicate measurements.



**Fig. S6** Bacterial respiration during the first half of the season (10 m depth, LTER - station B) measured with thymidine incorporation. Error bars represent standard deviation of the triplicates.

## Notes S1

### **<sup>14</sup>C net primary production – correction for the respiration (R) of the unlabelled carbon during the 24-h incubations**

The value of respiration R is derived from the experiment with *Fragilariopsis cylindrus* (see Fig. 4): it is the respiration in the dark normalized per the carbon content of *F. cylindrus* and converted in carbon units.

$R \text{ (pmol C pmol POC}^{-1} \text{ d}^{-1}) = (0.07 \text{ pmol O}_2 \text{ cell}^{-1} \text{ d}^{-1}) * (12 \text{ g mol}^{-1}) / (5 \text{ pg C cell}^{-1}) / (1.4 \text{ mol O}_2 / \text{mol C})$ . The carbon content per cell was derived from the cell volume, using the relationship:  $\text{pgC cell}^{-1} = 0.288 * \text{volume}^{0.811}$  established in Menden-Deuer & Lessard (2000). For each Palmer Station sampling date R was multiplied by the values of POC for that day (Young *et al.*, accepted) and subtracted from each <sup>14</sup>C NPP rates.

## Notes S2

### **Determining GPP and NCP Rates from triple oxygen isotope and dO<sub>2</sub>/Ar**

Rates of gross primary production (GPP) were calculated in three different ways from triple oxygen isotopes measured in situ at 10 m water depth (Table S2 and S3).

(1) The first method is the “typical” method employed, assuming steady state and that the samples are collected in the mixed layer (this assumption is based on an average calculated Ekman depth of 15 m throughout the season; Brody and Lozier (2014)). Our approach for

steady-state GPP calculations uses Eqn7 in Prokopenko *et al.* (2011).

The photosynthetic end-members used were  $\delta^{17}\text{O}_p = -10.12$  and  $\delta^{18}\text{O}_p = -20.014$  (Luz & Barkan, 2011). The equilibrium values for  $\delta^{18}\text{O}_{\text{eq}}$  were calculated using the equation from Benson & Krause (1980):  $\delta^{18}\text{O}_{\text{eq}} = -0.74 + 427/(T+273)$  where T is the temperature in Celsius. The equilibrium value of  $\delta^{17}\text{O}_{\text{eq}}$  was calculated from  $\delta^{18}\text{O}_{\text{eq}}$  and the measured value of  $^{17}\Delta_{\text{eq}} = 8$  per meg.

(2) The second method assumed samples were collected below the mixed layer and were not in steady state using Eqn 6 from Prokopenko *et al.* (2011). This equation requires values of the  $\text{O}_2$  concentration. However, some  $\text{O}_2$  concentrations were not available for the month of January (when steady state conditions were likely applicable anyway). The value of  $^{17}\Delta$  was calculated iteratively at each time point assuming no gas exchange with the atmosphere (since samples are from below the mixed layer). Because of upward mixing of oxygen and thus erosion of the  $^{17}\Delta$  anomaly, these calculations likely yield an underestimate of GPP.

(3) The third method assumed that samples were in the mixed layer under non-steady state conditions, thus providing an upper bound estimate of GPP. In this case, Eqn 6 from Prokopenko *et al.* (2011) was used, which includes a gas transfer velocity, k, calculated using a wind-speed dependent parameterization of mixed layer gas exchange coefficients (Wanninkhof, 1992) and a 14 d weighted average (Reuer *et al.*, 2007). Negative GPP values were sometimes obtained from this

method, reflecting unaccounted processes such as vertical mixing.

Rates of net community production (NCP) were calculated using the same assumptions: (1) steady state and within mixed layer, (2) non-steady state and below mixed layer, (3) non-steady state and within mixed layer. Results from all three calculations are listed in the supplementary tables. For steady state conditions,  $NCP = \Delta(O_2/Ar)[O_2]_{sat} k / \rho$  where  $\Delta(O_2/Ar)$  is the biological oxygen supersaturation defined as  $\Delta(O_2/Ar) = (O_2/Ar)_{meas} / (O_2/Ar)_{eq} - 1$ ,  $[O_2]_{sat}$  is the saturated  $O_2$  concentration as calculated from temperature and salinity data using the formulation of Garcia and Gordon (1992),  $k$  is the gas transfer velocity ( $k = 0$  if sample assumed below mixed layer), and  $\rho$  is the density of water. For non-steady state conditions,  $NCP = \Delta(O_2/Ar)[O_2]_{sat} k / \rho - dO_{2bio}/dt$  where  $O_{2bio}$  is the fraction of oxygen resulting from biological production and is estimated as  $O_{2bio} = \Delta(O_2/Ar)[O_2]_{sat}$  (Cassar *et al.*, 2011)

### **Notes S3**

#### **Electron flow measurements – correction of the artefact.**

The JTS-10 introduces an instrument artefact during the first few ms following the onset of darkness due to the artifact when measurements are made very rapidly; this is important during the first few milliseconds after the onset of darkness (in our experiments all the data for  $0 < t < 11.2$  ms). This artefact is dependent on the light transmitted by each sample and thus is the same with and without the addition of DCMU in our

experiment. In the presence of DCMU when the rate of  $P_{700}$  reduction is slower, this artefact can then be overcome by using an exponential fit ( $A \cdot e^{-t/b} + C$ ) of the points non-affected by the artefact ( $t=0$  and  $t > 11.2$  ms). The reduction rate is obtained as the first order derivative at  $t=0$ :  $A/b$ . The difference between the corrected rate and the measured data gives a correction for the artefact that can then be applied to the experiment in the absence of DCMU.

#### **Notes S4**

##### **Bacteria productivity – thymidine measurements**

Bacterial productivity was measured during the afternoon using 2h incubations with  $^3\text{H}$ -thymidine, following the method described in (Fuhrman & Azam, 1982). During the season, the maximum respiration at 10m ( $\sim 8 \mu\text{mol C l}^{-1} \text{d}^{-1}$ ) occurred right after the bloom (14 December; Fig. S6). No  $^{18}\text{O}$  incubation was performed during this sampling day but, as comparison, on the 18 December we measured  $\sim 13 \mu\text{mol C l}^{-1} \text{d}^{-1}$  (Fig. 1a) of respiration in the light from  $^{18}\text{O}$  incubation compared to  $\sim 2.6 \mu\text{mol C l}^{-1} \text{d}^{-1}$  based on thymidine data (Fig. S6).

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Table S1

Summary of data from incubations with H<sub>2</sub><sup>18</sup>O. Gross photosynthesis (GP) and net bottle production in the light (NBP<sub>L</sub>) are given in μmol O<sub>2</sub> L<sup>-1</sup> d<sup>-1</sup>. When available, the standard deviation is from duplicate. The photosynthetic quotient is calculated from C/N ratios reported in Young *et al.*

(accepted) and derived from electrons balance:  $PQ = \frac{mol\ O_2}{mol\ C} = \frac{\frac{1}{4}mol\ e^-}{mol\ C} = 1 + 2 * \frac{N}{C}$ . The average chlorophyll *a* in the bottle during each incubation is given in μg L<sup>-1</sup>. The average surface PAR (photosynthetically-active radiation) during each incubation is given in μE m<sup>-2</sup> s<sup>-1</sup>. The duration of each incubation is given in hours. The temperature (T) at 10m at Station B for that day is given in °C (in red are estimates of the temperature at 10m based on the two nearest days).

date	GP	Std dev GP	NBP <sub>L</sub>	Std dev NBP <sub>L</sub>	PQ	avg Chl a	avg PAR	duration	T
07/11/2012	24.35	0.69	-3.30	0.33	1.37	5.7	442	0.26	-1.4
14/11/2012	17.58	0.20	10.97	14.70	1.40	4.9	263	0.17	-1.3
19/11/2012	33.05	7.88	22.96	2.85	1.52	8.5	288	0.25	-1.2
27/11/2012	103.14	2.49	92.44	2.78	1.39	23.5	348	0.25	-0.6
04/12/2012	73.00	1.11	66.10	4.55	1.43	13.1	637	0.19	-0.5
10/12/2012	66.60	6.44	70.02	6.34	1.41	19.3	664	0.25	-0.4
18/12/2012	4.42	-	-15.49	-	1.44	1.5	480	0.32	0.0
31/12/2012	3.38	0.01	6.90	0.63	1.47	0.7	278	0.29	0.4
28/01/2013	1.92	-	9.06	-	1.64	0.7	317	0.26	1.8
25/02/2013	12.84	1.30	3.91	7.08	1.44	2.2	198	0.32	1.3
06/03/2013	12.06	0.58	21.66	2.64	1.21	3.2	300	0.34	1.3

Table S2

Summary of data from LTER-station B, 10m depth, to estimate Gross and Net production from  $dO_2/Ar$  and triple isotope composition, including: date of sampling, sea surface temperature (T, °C), sea surface salinity (S, psu), mixed layer depth (MLD, m, derived from T and S using 0.125 kg m<sup>-3</sup> density-difference criterion), biological  $O_2$  supersaturation ( $\Delta O_2/Ar$ , in %),  $^{17}\Delta$  (per meg),  $\delta^{17}O$  of the dissolved  $O_2$  (*per mil*),  $\delta^{18}O$  of the dissolved  $O_2$  (*per mil*), measured  $O_2$  concentration ( $\mu\text{mol kg}^{-1}$ ), gas transfer velocity (k, m d<sup>-1</sup>), amount of  $O_2$  due to biological change ( $O_2^{\text{bio}}$ ,  $\mu\text{mol kg}^{-1}$ ), estimates of NCP, GPP ( $\mu\text{mol } O_2 \text{ L}^{-1} \text{ day}^{-1}$ ) and the NCP/GPP ratios using a steady state and within mixed layer assumptions. The standard deviation of the duplicates for the rates and ratios are given in parenthesis (when available). The ratios are the average of the net over gross ratios for each duplicate. For the values marked with a star (bloom peaks), see Table S3 for the non-steady-states calculations.

Date	T	S	MLD	$\Delta O_2/Ar$	$^{17}\Delta$	$\delta^{17}O$	$\delta^{18}O$	[ $O_2$ ]	k	$O_2^{\text{bio}}$	GPP	NCP	NCP/GPP
18/11/2012	-1.29	33.78	14	5.65	50	-0.334	-0.741	372.6	2.5	20.6	14 (1.8)	3.9 (0.03)	0.28 (0.03)
23/11/2012	-0.95	33.88	13	4.15	50	-0.28	-0.636	367	2.5	14.9	13.9 (2.3)	2.8 (0.03)	0.21 (0.03)
30/11/2012	-0.38	33.78	12	31.37	99	-1.754	-3.574	467.6	1.6	111.3	26.6* (2.7)	15.1* (0.01)	0.57* (0.06)
5/12/2012	-0.37	33.85	10	5.66	57	-0.447	-0.972	356.2	1.3	20.1	11.5 (0.5)	2.7 (0.02)	0.23 (0.01)
12/12/2012	0.59	33.88	6	32.31	105	-1.823	-3.718	362.5	1.5	111.6	33.3* (4.6)	17.7* (0.06)	0.53* (0.07)
18/12/2012	0.28	33.86	7	-0.53	59	-0.065	-0.239	352.2	1.2	-1.8	11.5 (1.8)	-0.2 (0.03)	-0.02 (0.00)
23/12/2012	0.55	33.77	5	0.9	58	-0.099	-0.304	352.2	0.8	3.1	7.7 (1.4)	-0.2 (0.00)	-0.03 (0.01)
2/1/2013	1.11	33.4	5	-2.31	50	0.151	0.195	-	0.7	-7.9	5.2 -	-0.6 -	-0.11 -
8/1/2013	0.4	33.71	15	-0.4	61	-0.134	-0.377	-	2.3	-1.4	14.9 -	-0.2 -	-0.01 -
14/01/2013	1.57	33.65	7	1.44	54	-0.032	-0.165	-	1.4	4.9	11 (1.1)	0.7 (0.01)	0.06 (0.01)
21/01/2013	1.62	33.47	5	1.01	47	0.045	-0.005	-	1.1	3.4	7.4 -	0.4 -	0.05 -
31/01/2013	1.52	33.57	10	0.92	53	0.044	-0.016	328.3	1.4	3.1	10.5 (0.2)	0.4 (0.04)	0.04 (0.00)
18/02/2013	1.01	33.49	14	0.36	44	0.241	0.381	372.8	2.2	1.2	9.8 (0.9)	0.2 (0.03)	0.02 (0.01)
22/02/2013	1.3	33.54	9	2.58	53	0.032	-0.04	368.1	1.4	8.8	10.6 -	1.2 -	0.12 -
25/02/2013	1.15	33.34	4	-0.19	63	0.172	0.211	375	1	-0.7	10.5 -	-0.1 -	-0.01 -
1/3/2013	0.87	33.28	5	0.12	44	0.167	0.238	364.5	1.2	0.4	7.1 -	0.1 -	0.01 -

The rates and ratios were calculated assuming the samples were within the mixed layer, using the listed MLD values when >10m and 10m otherwise.

We used a photosynthetic end member of  $\delta^{17}O_p = -10.12$  and  $\delta^{18}O_p = -20.014$  (Luz & Barkan, 2011)

$\delta^{18}O_{\text{eq}}$  was calculated according to Benson and Krause (1980) with the temperature dependent formula:  $-0.74 + 427/(T+273)$ . From that  $\delta^{17}O_{\text{eq}}$  was calculated assuming a  $^{17}\Delta_{\text{eq}} = 8$  per meg.

Table S3

Derived rates (in  $\mu\text{mol O}_2 \text{ L}^{-1} \text{ day}^{-1}$ ) of gross primary production (GPP) and net community production (NCP) using a non-steady state assumption. The corresponding date is the end date of the period for which the rates and ratios were calculated. Terms labelled with an \* represent rates and ratios assuming the samples were above the mixed layer, while non-labelled terms assume the samples were taken below the mixed layer. The standard deviation of the duplicates for the rates and ratios are given in parenthesis (when available). The ratios are the average of the net over gross ratios for each duplicate. Dates when  $\text{O}_2$  concentrations were not available prevented the calculations of GPP. Negative GPP are non-physical and are likely a result of physical processes not included in our calculations. Ratios of NCP/GPP at dates when GPP was found negative were not calculated.

Date	GPP		NCP		NCP/GPP		GPP*		NCP*		NCP*/GPP*	
23/11/2012	-0.1	(2.2)	-1.1	(0.03)	-	-	13.8	(4.5)	1.7	(0.06)	0.13	(0.04)
30/11/2012	20.8	(3.3)	13.8	(0.02)	0.67	(0.11)	47.4	(6.1)	28.8	(0.03)	0.61	(0.08)
5/12/2012	-15.9	(0.5)	-18.2	(0.04)	-	-	-4.3	(1.0)	-15.6	(0.06)	-	-
12/12/2012	16.1	(3.7)	13.1	(0.05)	0.83	(0.19)	49.4	(8.2)	30.7	(0.11)	0.63	(0.10)
18/12/2012	-14.7	(1.5)	-18.9	(0.04)	-	-	-3.2	(3.3)	-19.1	(0.08)	-	-
23/12/2012	-0.2	(2.8)	1	(0.03)	-	-	7.5	(4.2)	1.3	(0.04)	0.2	(0.12)
2/1/2013	-	-	-1.1	-	-	-	-	-	-1.7	-	-	-
8/1/2013	-	-	1.1	-	-	-	-	-	0.9	-	-	-
14/01/2013	-	-	1	-	-	-	-	-	1.7	-	-	-
21/01/2013	-	-	-0.2	-	-	-	-	-	0.2	-	-	-
31/01/2013	0.9	(0.1)	0	(0.03)	-0.03	(0.03)	11.5	(0.3)	0.4	(0.07)	0.04	(0.01)
18/02/2013	-0.9	(0.3)	-0.1	(0.01)	-	-	8.9	(1.2)	0.1	(0.04)	0.01	(0.01)
22/02/2013	4.1	-	1.9	-	0.46	-	14.7	-	3.1	-	0.21	-
25/02/2013	6.9	-	-3.1	-	-0.45	-	17.5	-	-3.2	-	-0.19	-
1/3/2013	-8.8	-	0.3	-	-	-	-1.7	-	0.3	-	-	-

We used a photosynthetic end member of  $\delta^{17}\text{O}_p = -10.12$  and  $\delta^{18}\text{O}_p = -20.014$  (Luz & Barkan, 2011)

$\delta^{18}\text{O}_{\text{eq}}$  was calculated according to Benson and Krause (1980) with the temperature dependent formula:  $-0.74 + 427/(T+273)$ . From that  $\delta^{17}\text{O}_{\text{eq}}$  was calculated assuming a  $^{17}\Delta_{\text{eq}} = 8$  per meg. When values of  $\delta^{18}\text{O}$  and  $\delta^{17}\text{O}$  were needed in the calculations we chose the final values for the period rather than the average.

## References

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