Supporting Online Material for

Transatlantic Abundance of the N₂-Fixing Colonial Cyanobacterium

*Trichodesmium*

Cabell S. Davis* and Dennis J. McGillicuddy

*To whom correspondence should be addressed. E-mail: cdavis@whoi.edu


DOI: 10.1126/science.1123570

This PDF file includes

- Materials and Methods
- Figs. S1 to S4
- Table S1
- References
**Supporting Online Material**

**Methods**

*VPR*—As discussed extensively elsewhere *(1-11)*, the VPR yields abundance that are in close agreement with data from standard net tows for robust plankton (i.e., not destroyed by net sampling), and the non-invasive optical sampling approach also quantifies delicate forms such as gelatinous plankton, marine snow, and colonial forms such as *Trichodesmium*.

The automatic identification methods used in processing the VPR images, has been shown to be nearly as accurate as human-based manual sorting of images *(5, 12, 13)*. For the present study, our original shape-based neural network method was used *(5)*. Images were automatically sorted into 15 taxonomic categories and false positives manually removed; abundances then were corrected by dividing by the probability of detection (true positives/total) determined from a confusion matrix of training images *(5)*. Probability of detection was 0.62 and 0.48 for tuffs and puffs, respectively, and the corrected abundances can be expected to be close approximations to the human sorted result *(5, 13)*.

*SLA*—maps were produced by objective analysis of satellite altimetry measurements from TOPEX/Poseidon, Jason, Geosat Follow-On, and European Remote Sensing platforms. The data streams were made available through the Colorado Center for Astrodynamics Research Northwestern Atlantic Near Real-Time Altimeter Data Viewer *(14)*; see http://www-ccar.colorado.edu/~realtime/nwatlantic-real-time_ssh).]
**N-fixation**—Higher than expected abundance of *Trichodesmium* colonies at depth has potential importance to water column N-fixation. Although N-fixation is a function of light intensity, which decreases exponentially with depth, it is important to determine the potential contribution of the deeper *Trichodesmium* colonies to water column N-fixation. The total N-fixation rate at each depth was computed as the product of colony abundance and per-colony N-fixation rate, and the water column mean then was computed. Colony abundances were obtained from VPR data and compared to published data from net tows in the Sargasso Sea ([15, 16](#)) (see Fig. S4).

Two separate published rates of N-fixation as a function of light intensity were used, yielding linear and nonlinear relationships respectively. The linear relationship is given by $Y = 0.5 + 1.4L_Z$, where $Y$ is N-fixation rate as percent of the surface rate, and $L_Z$ is percent of surface light at depth $Z$ up to 60%, after which N-fixation is the same as the maximal surface rate ([16](#)) (Fig. S1). The nonlinear relationship, given by $Y = L_Z/(3.91 + L_Z)$, was fit to a separate set of data on N-fixation rate versus light intensity ([17](#)) (Fig. S1). The linear function, below 60% surface light intensity (>10 m depth), causes per-colony N-fixation rate to decrease exponentially with increasing water depth. The non-linear function causes a more gradual decrease in N-fixation with depth (Figs. S1, S2), thus increasing the relative importance of deeper colonies to the water column total. Thus the linear function is a more conservative estimate of subsurface N-fixation compared with the nonlinear function, since N-fixation rate decreases less markedly with declining light levels in the upper water column ([17, 18](#)) (Figs. S1, S2).

Light curves were computed for 928 daytime VPR profiles, yielding a mean extinction coefficient of 0.05 m⁻¹ (s.d. = 0.009) (Fig. S2). An average surface N-fixation rate of 0.7 nmol N
colony$^{-1}$h$^{-1}$ was used (16, 19), corresponding to intact, diver-collected, colonies incubated for 6-8 h (16) and agreeing with modeled rates (19). These rates are higher than those found in net-collected colonies (16, 17), possibly due the non-invasive diver-collection method being less damaging to the colonies (16). (The absolute surface N-fixation rate is not critical here, since our primary aim is to determine the relative impact on existing water column N-fixation estimates of the new abundance data.) The average per colony rate, based on 7-h incubation, was modified to a daily rate by first using a sine function for surface light intensity during the 12-h daytime period. This adjustment reduced the average hourly rate over 12 h to 0.5147 nmol N colony$^{-1}$h$^{-1}$ (i.e., 0.7 · 0.7353), and a 24 h average of 0.2574 nmol N colony$^{-1}$h$^{-1}$. 
Fig. S1. N-fixation versus light functions. Rectilinear curve and data (triangles) from (16), Nonlinear (Michaelis-Menten) curve fit to data (circles) from (17). (Data are per-colony N-fixation rate (% of surface) versus % Surface light intensity).

Fig. S2. Light intensity (solid curve, $I=100e^{-0.05Z}$) and N-fixation rate as a function of depth using the rectilinear (dotted) and curvilinear (dashed) functions shown in Fig. S1.
Fig. S3. Vector plot of ocean currents from the ship’s hull-mounted Acoustic Doppler Current Profiler (ADCP) overlying the contour map of sea level anomaly (sea surface height anomaly). This is a very high resolution figure, and zooming to particular regions reveals the surface velocity structure of the individual eddies. Note the clockwise flow in the cold (cyclonic) eddies (blue) and the counterclockwise flow in the warm (anticyclonic) eddies (red). This plot shows that the altimetry data closely matches the measured surface currents.
Fig. S4. Vertical distribution of *Trichodesmium* abundance from the present study (solid line with error bars) compared with previous published data from the Sargasso Sea [circles (16), triangles (15), inverted triangles (20)] and with the empirical curve from (16). Data were normalized to compare relative abundance versus depth. (Absolute surface concentrations were similar among studies.) Note relative abundance at depth in the present study is higher than all previous data except one data point at 25 m.
Table S1. Nitrogen Fixation rates estimated from VPR-based and Net-based colony abundances and linear and nonlinear functions of per colony N-fixation rate versus light (Figs. S1, S2).

<table>
<thead>
<tr>
<th></th>
<th>Linear model - basin</th>
<th>Nonlinear - basin</th>
<th>Nonlinear - western</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puffs VPR nmol m⁻³d⁻¹</td>
<td>2.26</td>
<td>4.50</td>
<td>7.19</td>
</tr>
<tr>
<td>Puffs Net nmol m⁻³d⁻¹</td>
<td>0.68</td>
<td>1.03</td>
<td>1.44</td>
</tr>
<tr>
<td>Ratio</td>
<td>3.29</td>
<td>4.36</td>
<td>5.00</td>
</tr>
<tr>
<td>Tufts VPR nmol m⁻³d⁻¹</td>
<td>4.13</td>
<td>6.22</td>
<td>25.20</td>
</tr>
<tr>
<td>Tufts Net nmol m⁻³d⁻¹</td>
<td>1.42</td>
<td>2.14</td>
<td>9.43</td>
</tr>
<tr>
<td>Ratio</td>
<td>2.90</td>
<td>2.90</td>
<td>2.67</td>
</tr>
<tr>
<td>Tufts VPR µmolN₂ m⁻²d⁻¹</td>
<td>6.45</td>
<td>9.71</td>
<td>39.31</td>
</tr>
<tr>
<td>Puffs VPR µmolN₂ m⁻²d⁻¹</td>
<td>3.52</td>
<td>7.02</td>
<td>11.23</td>
</tr>
<tr>
<td>Total VPR µmolN₂ m⁻²d⁻¹</td>
<td>9.98</td>
<td>16.7</td>
<td>50.54</td>
</tr>
<tr>
<td>Tufts Net µmolN₂ m⁻²d⁻¹</td>
<td>2.22</td>
<td>3.34</td>
<td>14.71</td>
</tr>
<tr>
<td>Puffs Net µmolN₂ m⁻²d⁻¹</td>
<td>1.07</td>
<td>1.61</td>
<td>2.24</td>
</tr>
<tr>
<td>Total Net µmolN₂ m⁻²d⁻¹</td>
<td>3.29</td>
<td>4.95</td>
<td>16.96</td>
</tr>
</tbody>
</table>
SOM Literature Cited

18. C. M. Holl, PhD, Georgia Institute of Technology (2004).