“Over appropriate space and time scale, the upward flux of nitrate, the uptake of nitrate and the downward flux of particulate N should be in balance”

New production assessment

- Use of stable isotope techniques to determine:
  - Primary production PP ($^{13}\text{C}$)
  - $f$-ratio ($^{15}\text{N}$)
  - New production $\text{NP} = f$-ratio $\times$ PP
Data Analysis
A model comparison approach*

Parameter estimates: C and N flux rates

Uncertainty assessment

Statistics

Optimization

Numerical integration

Mass balance differential equations

Field measurements

*Elskens et al. [2005] Global Biogeochemical Cycles, 19
Methodological constraints during Aloha

• DIN concentrations below the limit of detection
  ⇒ Simple statistical methods for analyzing the mean and variance of this censored data set
  ⇒ RSD% on initial enrichment up to 50%
  ⇒ Large uncertainty on uptake rate estimates

• $^{15}$N tracer additions >> ambient DIN level
  ⇒ A correction is needed for estimating ambient uptake rates
  ⇒ Adjusted uptake rates based on first order kinetic*

* Eppley et al. [1977] Marine Biology, 39
DIN uptake rates

Aloha

K2

% of DIN uptake rate

NH4  NO3  NO2  N2  NH4  NO3

9%  6%  4%  n = 32  82%  18%
Utilization of N substrates vs depth

% of DIN uptake rate

Depth (m.)
Vertical profiles of $f$-ratio at Aloha

Integrated $f$-ratio: 0.12 ± 0.05
Range (min-max): 0.07 – 0.20
Vertical profiles of $f$-ratio at K2

Integrated $f$-ratio: $0.17 \pm 0.05$
Range (min-max): $0.10 - 0.24$
### Representative value of surface nitrate specific uptake rates and f-ratio

<table>
<thead>
<tr>
<th>Region</th>
<th>Specific UNO3 d⁻¹</th>
<th>f-ratio %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eutrophic</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.28 – 0.84</td>
<td>57 – 84</td>
</tr>
<tr>
<td>Peru, Baja Calif…</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oligotrophic</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.006 – 0.011</td>
<td>3 - 21</td>
</tr>
<tr>
<td>Sargasso sea, Mediterranean sea…</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aloha</strong></td>
<td>0.002 – 0.006</td>
<td>7 - 20</td>
</tr>
<tr>
<td><strong>HNLC</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.03 – 0.06</td>
<td>36 - 48</td>
</tr>
<tr>
<td>Antarctic, Northeast Pacific…</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K2</strong></td>
<td>0.02 – 0.06</td>
<td>10 - 24</td>
</tr>
</tbody>
</table>

Compilation of data from Dugdale and Wikerson, [1992]. Environmental Science Research, 4
Vertical profiles of primary production ($^{13}$C) at Aloha

Integrated PP: $209 \pm 30$ mg C m$^{-2}$ d$^{-1}$
Range (min-max): 143 – 240
Vertical profiles of primary production ($^{13}$C) at K2

Integrated PP: 470 ± 107 mg C m$^{-2}$ d$^{-1}$
Range (min-max): 348 – 585
Comparison between $^{13}$C and $^{14}$C PP estimates

Paired t-test $p = 0.324$
Vertical profiles of new production at Aloha

Integrated PNEW 30 ± 11 mg C m^{-2} d^{-1}
Range (min-max) 12 – 42
Vertical profiles of new production at K2

Integrated PP 101 ± 50 mg C m⁻² d⁻¹
Range (min-max) 50 – 171
Primary and new production variability at Aloha

Detecting process changes with a CUSUM technique
Primary and new production variability at K2

Detecting process changes with a CUSUM technique

![Graph showing variability in production over Julian days with t-test p-values](image-url)
Primary and new production: a summary

<table>
<thead>
<tr>
<th>Station</th>
<th>PP mg C m(^{-2}) d(^{-1})</th>
<th>PNEW mg C m(^{-2}) d(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aloha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23/06 – 27/06/04</td>
<td>209 ± 30</td>
<td>18 ± 5</td>
</tr>
<tr>
<td>29/06 – 07/07/04</td>
<td>10 - 12</td>
<td>38 ± 6</td>
</tr>
<tr>
<td>Ratio to POC flux at 150m (NBST)</td>
<td>10 - 12</td>
<td>0.8 - 1</td>
</tr>
<tr>
<td>K2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31/07 – 04/08/05</td>
<td>581 ± 4</td>
<td>151 ± 30</td>
</tr>
<tr>
<td>06/08 – 17/08/05</td>
<td>392 ± 35</td>
<td>72 ± 21</td>
</tr>
<tr>
<td>Ratio to POC flux at 150m (NBST)</td>
<td>10 - 17</td>
<td>2 - 3</td>
</tr>
</tbody>
</table>
Trichodesmium: specific uptake rate day$^{-1}$
Trichodesmium: Absolute uptake rate µM day⁻¹

![Graphs showing uptake rates for Trichodesmium samples.](image-url)