Parameterizing Nitrification & Closure Term

Hakase Hayashida
Developing a pelagic ecosystem model for the Arctic Ocean
What is nitrification?

- A two-step oxidation process which utilizes ammonia to produce nitrate:
  - Ammonia oxidation (NH3/NH4+→NO2)
  - Nitrite oxidation (NO2→NO3-)
- Traditionally (prior to 2004), nitrification was thought to performed mainly by ammonia-oxidizing bacteria (AOB) in the aphotic zone.
**Table 33.2** Nitrification model descriptions

<table>
<thead>
<tr>
<th>Reference</th>
<th>Nitrification model</th>
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</thead>
<tbody>
<tr>
<td>Wroblewski, 1977</td>
<td>1st-order $f(NH_4)$</td>
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<tr>
<td>Sarmiento <em>et al.</em>, 1993</td>
<td>1st-order $f(NH_4)$, $z &gt; 123$ m</td>
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<td>Kawamiya <em>et al.</em>, 1995</td>
<td>1st-order $f(NH_4)$ with T-dependent coefficient</td>
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<tr>
<td>Chai <em>et al.</em>, 1996</td>
<td>1st-order $f(NH_4)$, $z &gt; 120$ m</td>
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<tr>
<td>Levy <em>et al.</em>, 1998</td>
<td>1st-order $f(NH_4)$ with T-dependent coefficient</td>
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<tr>
<td>Bissett <em>et al.</em>, 1999</td>
<td>hyperbolic $f(NH_4)$, $E &lt; 1 \mu$mol m$^{-2}$ s$^{-1}$</td>
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<tr>
<td>McClain <em>et al.</em>, 1999</td>
<td>Hyperbolic $f(E)$</td>
</tr>
<tr>
<td>Walsh <em>et al.</em>, 1999</td>
<td>fixed rate, $E &lt; 0.1E_o$, $[NH_4] \geq 0.1$ $\mu$M</td>
</tr>
<tr>
<td>Tian <em>et al.</em>, 2000</td>
<td>1st-order $f(NH_4)$, hyperbolic $f(E)$, $E &lt; 0.1E_o$</td>
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<tr>
<td>Christian <em>et al.</em>, 2002a</td>
<td>1st-order $f(NH_4)$, $z &gt; 120$ m</td>
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<tr>
<td>Denman, 2003</td>
<td>1st-order $f(NH_4)$ $\times$ nonlinear $z$ profile</td>
</tr>
</tbody>
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$E$ — irradiance; $E_o$ — surface irradiance; $T$ — temperature; $z$ — depth.
Recent discoveries

● Functional gene ammonia monooxygenase (amoA) (Venter et al. 2004).
  ○ A significant contribution from ammonia-oxidizing archaea (AOA), especially in ammonia oxidation (Wuchter et al., 2006).

● Nitrification occurs throughout the water column (Zehr & Kudela, 2013).
What limits/controls nitrification?  
(Hatzenpichler, 2012)

- NH4 concentration
- oxygen (Some AOA can adapt to low-oxygen environment.)
- temperature (Metabolism)
- light (species- and wavelength-specific photoinhibition.)
- pH (Uncertain. Some adaptability).
Summary

The diversity of organisms performing ammonia oxidation and nitrification is now known to span both the Bacterial and Archaeal domains of life. In contrast to the perception that this occurs primarily in the deep ocean, we now know that nitrification occurs at all depths in the ocean, potentially at rates significantly faster (days rather than months) than previously thought. (Zehr & Kudela, 2013)

Open questions (Hatzenpichler, 2012)

○ Separation of AOA and AOB (abundance, metabolism).
○ Co-dependence of AOA and NOB (nitrite-oxidizing bacteria).
Pelagic nitrification and denitrification rates in an Arctic fjord during early spring

Kotttekutu Padinchari Krishnan · Rupesh Kumar Sinha · Sivaramakrishnan Rajan
Developing a pelagic ecosystem model for the Arctic Ocean
Are closure terms appropriate or necessary descriptors of zooplankton loss in nutrient–phytoplankton–zooplankton type models?

Aditee Mitra*

Institute of Environmental Sustainability, Wallace Building, Swansea University, Singleton Park, Swansea SA2 8PP, United Kingdom

<table>
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<tr>
<th>Closure term</th>
<th>Function</th>
<th>Literature examples</th>
</tr>
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<tbody>
<tr>
<td>Linear</td>
<td>( \frac{dZ}{dt} = \ldots - \mu_2 Z )</td>
<td>(Evans and Parslow, 1985; Wrobl 1989; Fasham et al., 1990; Beltra Carroll, 1994; Edwards and Brinc)</td>
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<tr>
<td>Quadratic</td>
<td>( \frac{dZ}{dt} = \ldots - \mu_1 Z^2 )</td>
<td>(Steele and Henderson, 1981; Den Gargett, 1995; Fasham, 1995; Ed Brindley, 1996)</td>
</tr>
<tr>
<td>Hyperbolic</td>
<td>( \frac{dZ}{dt} = \ldots - \mu_2 Z^2/(k_6 + Z) )</td>
<td>(Frost, 1987; Fasham, 1993; Ross)</td>
</tr>
<tr>
<td>Sigmoid</td>
<td>( \frac{dZ}{dt} = \ldots - \mu_2 Z^3/(k_6^2 + Z^2) )</td>
<td>(Malchow, 1994)</td>
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