Benign de-nitrification in the subsurface environment

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*Presenting on behalf of our students, post-doc and colleagues Mr. Aldrin Rivas, Mr. Ahmed Elwan, Mr. Pete McGowan, Mr. Stephen Collins, Ms. Genevieve Smith, Ms. Heather Martindale, Dr. Uwe Morgenstern, Dr. Neha Jha, Dr. Andrew McMillian, Dr. Andrew Manderson, Dr. Lucy Burkitt, A/Professor David Horne, Professor Mike Hedley, Ms. Abby Matthews, and Dr. Jon Roygard
Periphyton (benthic algae)
Grows on the bed and on solid objects such as logs and stones in rivers

Associated with nutrient enrichment (excess of nutrients, nitrogen and phosphorus)
Sources and contributions to nutrient loadings?

- Pastoral farming
- Farm dairy effluent
- Industry, towns, and roads
- Septic tank human effluent disposal
- Crops

Predicts catchment N loss from root zone

Source: Environment New Zealand 2007, MfE.
**Manawatu Catchment @ Upper George**

**Nitrogen attenuation factor** ($AF_n$)

$$AF_n = \frac{N_{\text{rootzone}} - N_{\text{river}}}{N_{\text{rootzone}}}$$

$$= \frac{16.2 - 6.9}{16.2}$$

$$= 0.6$$

**Nitrogen assimilative capacity:**

Catchment average ~ 60% of root zone losses

**River N load (catchment average):**

$$N_{\text{river}} = 6.9 \text{ kg per ha per year}$$

Source: Elwan et al. (2015), Massey University
Nitrogen Attenuation Capacity

**Green**
- > 80% N reduction
- High Capacity Areas: Sustainable Land Use
  - Intensification

**Yellow**
- 50 – 80% N reduction
- Medium Capacity Areas: Reduce Nitrogen Leaching via
  - Best Effluent and Nutrient Management Practices

**Red**
- < 50% N reduction
- Low Capacity Areas: Duration controlled grazing
  - Sheep/Goat milking
  - Cut and Carry Systems

Example: The Danish national map of nitrate reduction classes.
(Source: Ernsten et al., 2008)
A collaborative, co-developed and co-funded research programme

Programme Co-ordination

Dr. Ranvir Singh
Assoc. Prof. Dave Horne
Dr. Uwe Morgenstern
Ms. Abby Matthews
Dr. Jon Roygard
Prof. Mike Hedley

Programme Partners

Massey University
Horizons Regional Council
Landcare Research Manaaki Whenua
Fertilizer & Lime Research Centre
Dairynz
GNS Science

National Science Challenges

Our Land and Water

Toitū te Whenua, Toi ora te Wai
Developing techniques, methods and models

Objective - Assess and map nutrient flow pathways and their potential attenuation

Four piezometers at depth ranging from 5.8 To 8.7 m below ground level (bgl)

Suction cups (depth, bgl)
- 200 cm
- 100 cm
- 60 cm
- 30 cm
In-field monitoring and observations

Source: Aldrin Rivas, PhD Student, Massey University

Study sites

1. Massey No. 1, Dairy
2. Pahiatua site, Dairy
3. Woodville site, Sheep & beef
4. Dannevirke site, Dairy

Source: Aldrin Rivas, PhD Student, Massey University
De-nitrification: the key nitrogen attenuation process

Methods:

- Lab incubations and in-field ‘push-pull’ tests
- Isotope tracer techniques
- **Excess N₂** (being developed by GNS Sciences)
- **Molecular techniques** (being developed by Massey FLRC and Landcare Research)

**Single Well ‘Push-Pull’ Test**

- Adding Acetylene, Bromide and Nitrate
- Groundwater extraction and analysis
- Test solution injection
De-nitrification: the key nitrogen attenuation process

Groundwater de-nitrification? benign or not-benign?

- Direct measurement of the terminal products of denitrification, $N_2O$ and $N_2$
- Direct measurement of the de-nitrifiers, $nirS$, $nirK$ and $nosZ$ genes

\[
\begin{align*}
\text{NO}_3^- & \xrightarrow{\text{Nar}} \text{NO}_2^- \\
\text{NO}_2^- & \xrightarrow{\text{Nir} (nirS, nirK)} \text{NO} \\
\text{NO} & \xrightarrow{\text{Nor}} \text{N}_2\text{O} \\
\text{N}_2\text{O} & \xrightarrow{\text{Nos} (nosZ)} \text{N}_2
\end{align*}
\]
Relationships between nitrogen attenuation and catchment characteristics

Nitrogen attenuation factor ($\text{AF}_n$) = $(\text{N}_{\text{rootzone}} - \text{N}_{\text{river}}) / \text{N}_{\text{rootzone}}$

Spatial distribution of the nitrogen attenuation factor for 15 sub-catchments in the Tararua Groundwater Management Zone (TGWMZ) (Elwan et al, 2015).

Table 1: Results of linear regression analysis between the $\text{AF}_n$ values and catchments characteristics

<table>
<thead>
<tr>
<th>Catchment Characteristics</th>
<th>$\text{AF}_n$</th>
<th>$R^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-drained (e.g., soils with drainage class 5) soils*</td>
<td>-0.35</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>Fine textured (e.g., clay loam) soils</td>
<td>0.37</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>Base Flow Index (BFI)</td>
<td>-0.31</td>
<td>&lt;0.05</td>
<td></td>
</tr>
</tbody>
</table>

*Soils with drainage class 5, in the Fundamental Soil Layer "FSL", are well-drained soils.
Prediction of nitrogen loads in the Rangitikei River

Model - Variable nitrogen attenuation factor (based on soil and rock types – FSL and QMAP layers)

$$\text{River N load (ton yr}^{-1}\text{)} = m \sum_{i=1}^{n} A_i \times N_i \times (1 - AF_{NRT})(1 - AF_{NST})$$

Comparison of predicted vs. measured average annual soluble inorganic nitrogen (SIN) loads in different sub-catchments of the river

Prediction of nitrogen loads in the Rangitikei River

De-intensify (~9,800 ha) and Intensify (~83,000 ha) landuse (S3)

Root zone N losses increase by 55%

River N load decreases by 6%

Concluding Remarks

• Opportunity to spatially align intensive high-value primary production with naturally high contaminant attenuation capacity areas

• Reduce water quality impacts, hence sustain and/or enhance cultural resources, mahinga kai, taonga species.

• Collaborative, co-developed, co-funded research programme

• Developing cost-effective practical techniques, methods and models

• Aligned with the OLW Challenge ‘Sources and Flows’ & ‘Land Suitability’ programmes for wider applications
Thank you – Questions and suggestions please!