TOO MUCH OF A GOOD THING:
ENVIRONMENTAL IMPACTS OF INCREASING
ATMOSPHERIC NITROGEN DEPOSITION
ON PEATLANDS

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Impacts of atmospheric nitrogen deposition: responses multiple plant and soil parameters across contrasting ecosystems in long-term field experiments

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Nonlinear responses to nitrogen and strong interactions with phosphorus additions drastically alter the structure of a high arctic ecosystem

Seth J. T. Arens,1,2 Patrick F. Sullivan,1 and Jeffrey M. Welker1

Who Put the N in PristiNe?
Impacts of Nitrogen Enrichment in Fragile Mountain Environments

Rachel Hellwell
Andrea Britton
Shelia Gibbs
Julie Fisher
Julian Aherne

AMBIO 2012, 41:235–246
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Effects of Atmospheric Nitrogen Deposition on Remote Freshwater Ecosystems

Fabio Lepori, François Keck

Long-Term Change in the Nitrogen Cycle of Tropical Forests

Peter Hietz,1* Benjamin L. Turner,2 Wolfgang Wanek,3 Andreas Richter,1 Charles A. Nock,2 S. Joseph Wright2

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ejournal homepage: www.elsevier.com/locate/envpol

Review
Nitrogen deposition effects on Mediterranean-type ecosystems: An ecological assessment

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Environmental Pollution 155 (2006) 2265–2279
Overview

1. Worldwide trends of N deposition

2. Effects at organism level
   2.1 *Sphagnum* mosses and vascular plants
   2.2 Soil microbes

3. Effects at community level
   3.1 Litter and organic matter decomposition
   3.2 Gas exchange

4. Interaction of N with climate warming

5. Open questions
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5. Open questions
1. Worldwide trends of N deposition

**Background**

**Anthropogenic**
1. Worldwide trends of N deposition

Fritz Haber (1868-1934)  Carl Bosch (1874-1940)
Past, present and future of nitrogen deposition

Figure 2. Spatial patterns of total inorganic nitrogen deposition in (a) 1860, (b) early 1990s, and (c) 2050, mg N m$^{-2}$ yr$^{-1}$. 

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Nitrogen deposition and *Sphagnum* tissue chemistry

2. Effects at organism level

Fig. 1 Trend of mean (± SE) nitrogen (N) concentration in *Sphagnum* capitula along the gradient of atmospheric N deposition.

2. Effects at organism level

Sphagnum productivity


2. Effects at organism level

Reduced *Sphagnum* filtering ability

![Graph showing the relationship between atmospheric N deposition and corrected N concentration in bog water.](image)

- **DIN**
  - $y = 37x - 6.9$
  - $R^2 = 0.96, p < 0.01$
- **DON**
  - $y = 15x - 3.3$
  - $R^2 = 0.84, p < 0.01$

2. Effects at organism level

Response of vascular plant cover


Bragazza et al. (2012) *Global Change Biology* 18:1163
The “revenge of vascular plants”

Control (ambient N dep. = 0.2 g m$^{-2}$ yr$^{-1}$)

After 8 years of N fertilization (ambient N dep. + 3 g m$^{-2}$ yr$^{-1}$)

Interspecific competition: 
*Sphagnum* vs. vascular plants

2. Effects at organism level

Chong et al. (2012) *Écoscience* 19:89
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5. Open questions
2. Effects at organism level

Response of soil microbes to high N deposition

3.3. Nutrient deposition

Our knowledge of how nutrient deposition affects microbial population is rather fragmented. Indeed, while a large number of studies have looked at the long-term impact of nutrient deposition on vegetation and carbon cycling (e.g. Bubier et al., 2007; Juutinen et al., 2010; Limpens et al., 2006; Bragazza et al., 2012), only a few studies have looked at microorganisms and their response to increased nutrient deposition (Table 6). Enhanced N and S depo-
2. Effects at organism level


Bragazza et al. (2012) Global Ch. Biol. 18: 1163

Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163
Interspecific competition: *Sphagnum* vs. microbes

2. Effects at organism level

Limpens et al. (2003) *Oikos* 103: 59

Fig. 1. A Fruiting body of *Lyophyllum palustre*, B Necrotic *Sphagnum cuspidatum*, C Early infection around stem of *S. papillosum* and D Defoliated stem part of *S. papillosum*, also referred to as sign of infection.
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3. Effects at community level

Increased N content in peat litter enhances CO₂ release under laboratory conditions

Fig. 1. Hourly CO₂ emission from litter peat samples after 4 and 10 days of incubation in relation to atmospheric N deposition in study bogs. Relationships were explained by a logarithmic regression for both incubation periods \( y = 0.98 + 0.21 \ln(x), R^2 = 0.75, P < 0.01 \) and \( y = 0.49 + 0.11 \ln(x), R^2 = 0.73, P < 0.01 \), respectively. Each value is the mean (± 1 SE) of three to six litter peat samples.

Bragazza et al. (2006) *PNAS* 103: 1936
### N content in plant litter and short-term field decomposition

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Initial N concentration (mg g(^{-1}))</th>
<th>Initial P concentration (mg g(^{-1}))</th>
<th>Mass loss 1 year</th>
<th>Mass loss 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>13.0(^{b}) ± 0.36</td>
<td>0.84(^{a}) ± 0.05</td>
<td>38.9(^{b}) ± 1.7</td>
<td>62.8(^{a}) ± 4.4</td>
</tr>
<tr>
<td>Fertilized</td>
<td>15.4(^{a}) ± 0.25</td>
<td>0.76(^{b}) ± 0.09</td>
<td>44.0(^{a}) ± 5.7</td>
<td>66.0(^{a}) ± 9.8</td>
</tr>
<tr>
<td>Sphagnum fuscum</td>
<td>6.6(^{b}) ± 0.16</td>
<td>0.31(^{a}) ± 0.01</td>
<td>9.6(^{b}) ± 3.0</td>
<td>15.8(^{a}) ± 6.2</td>
</tr>
<tr>
<td>Control</td>
<td>15.7(^{a}) ± 0.95</td>
<td>0.29(^{b}) ± 0.02</td>
<td>14.1(^{a}) ± 3.4</td>
<td>18.9(^{a}) ± 4.2</td>
</tr>
<tr>
<td>Fertilized</td>
<td>14.2(^{a}) ± 0.24</td>
<td>0.87(^{a}) ± 0.01</td>
<td>44.9(^{a}) ± 6.9</td>
<td>65.4(^{a}) ± 4.9</td>
</tr>
<tr>
<td>Eriophorum vaginatum</td>
<td>14.8(^{a}) ± 0.41</td>
<td>0.85(^{a}) ± 0.04</td>
<td>37.8(^{b}) ± 2.8</td>
<td>59.7(^{b}) ± 14.6</td>
</tr>
</tbody>
</table>

Different superscripts for the same plant species indicate significant differences between treatments (Student t-test; \(P < 0.05\)). Mean values are based on five replicates for initial litter chemistry and on eight replicates for litter mass loss.

Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163
Nutrient retention in decomposing *Sphagnum* litter

**Nitrogen (N)**

- **Control**
- **Fertilized**

<table>
<thead>
<tr>
<th>Nutrient loss (%)</th>
<th>1 yr</th>
<th>3 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-80</td>
<td>-60</td>
</tr>
<tr>
<td>Fertilized</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Phosphorus (P)**

- **Control**
- **Fertilized**

<table>
<thead>
<tr>
<th>Nutrient loss (%)</th>
<th>1 yr</th>
<th>3 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fertilized</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Fertilized* treatment shows a significant increase in nutrient loss compared to *Control*, as indicated by the asterisks (*) and (**).

3. Effects at community level

Positive feedback on increasing soil N availability due to reduced N immobilization

Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163
Soil enzymatic activity

3. Effects at community level

...under laboratory conditions

...under field conditions

Bragazza et al. (2006) *PNAS* 103: 1936

Bragazza et al. *Unpublished data*
3. Effects at community level

Overall trends in litter accumulation with increasing N deposition

The increased productivity of vascular plants does not compensate for the reduced productivity of recalcitrant litter by *Sphagnum* plants
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5. Open questions
Lower NEE (net ecosystem exchange) after 5 years, but mainly due to a reduced photosynthetic rate of *Sphagnum* plants.

N deposition and N$_2$O emission: the role of vegetation as N sink

**Fig. 6.** Mean N$_2$O-N flux (+/- s.e.m) from the control (no added N) and N treated (oxidised (Nox), reduced (Nred) and ammonia (amm)) plots (~56 kg N ha$^{-1}$ yr$^{-1}$) at Whim bog in 2009 and 2010.

**Fig. 7.** Immobilization of N above and below ground, in the peat from the control (no added N) and N treated (oxidised (Nox), reduced (Nred) and ammonia (amm)) plots (~56 kg N ha$^{-1}$ yr$^{-1}$) at Whim bog in 2009.

CH$_4$ and N deposition: the role of pH, soil temperature and vegetation cover

Eriksson et al. (2010) *J. Geophysical Res.* 105: G04036
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The reduction in plant fresh weight after long-term exposure to high nitrogen deposition rates was not reflected in a significant reduction in dry weight, indicating adverse effects on capitulum morphology and cell anatomy, probably via a reduction in hyaline/chlorophyllous cell volume ratio. As a consequence, water content in high nitrogen treated plants reduced from 1960% to 1500%. According to Silvola (1990),

**Elevated atmospheric CO₂ and increased nitrogen deposition: effects on C and N metabolism and growth of the peat moss Sphagnum recurvum P. Beauv. var. mucronatum** (Russ.) Warnst

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Nutrient additions in pristine Patagonian *Sphagnum* bog vegetation

Fig. 2. Visible effects of treatments [Control (a), N-treatment (b), P-treatment (c), NP-treatment (d)] on *Sphagnum magellanicum*-dominated plots. Oblique photographs were taken after a dry spell in January 2009, when water levels were 35 cm below the surface, 15 cm lower than the average summer water level. For treatment details see Fig. 1.

...at community level

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Or visit our interactive blog at: www.peatbog.org

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5. **Open questions**
1. N deposition effect on decomposition of old organic matter

2. N deposition effect on root architecture, morphology and functioning

3. N deposition effect on soil microbial structure and enzymatic activity
Luca Bragazza (luca.bragazza@wsl.ch)
N deposition and N$_2$O emission

![Graph showing cumulative N$_2$O flux vs total N input]

*Higher N$_2$O emission with higher N availability*