MODELING NUTRIENT RETENTION IN THE COASTAL ZONE OF AN EUTROPHIC SEA - A MODEL STUDY IN THE STOCKHOLM ARCHIPELAGO

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Nutrient COcktails in the COAstial zone of the Baltic Sea

Identify major pathways of nutrients and organic material across the diversity of coastal ecosystems and assess management implications.
The coastal zone as a filter for nutrients

Retention
The coastal filter of nutrients

**Retention**

- Atmospheric load
- Point sources
- River load
- Study area
  - Temporary Retention
  - Permanent Retention
  - Outflow
  - Inflow

**Permanent retention**
- Burial
- Denitrification (nitrogen)

**Temporary retention**
- Changes in pelagic and benthic pools
Study Sites

- Stockholm Archipelago, 1990-2012
**Model system**

The Swedish Coastal zone Model (SCM)

- multi-basin 1D-model
- based on the equation solver PROgram for Boundary layers in the Environment (PROBE)
- coupled to the Swedish Coastal and Ocean Biogeochemical model (SCOBI)
- Vertical resolution 0.5-10 m
Model system, SCOBI

- inorganic nutrients
- nitrogen fixation
- particulate organic matter
- sediment
- oxygen
- hydrogen sulphide
- denitrification
- nitrification
- burial
Evaluation, model results

<table>
<thead>
<tr>
<th>Basin name</th>
<th>NoS occ</th>
<th>NoS Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandöfjärden</td>
<td>209</td>
<td>23</td>
</tr>
<tr>
<td>Kanholmsfjärden</td>
<td>206</td>
<td>23</td>
</tr>
<tr>
<td>Solöfjärden</td>
<td>213</td>
<td>23</td>
</tr>
<tr>
<td>Trälhavet</td>
<td>215</td>
<td>23</td>
</tr>
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<td>S. Vaxholmsfjärden</td>
<td>131</td>
<td>23</td>
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<tr>
<td>Stora Värtan</td>
<td>141</td>
<td>23</td>
</tr>
<tr>
<td>Strömmen</td>
<td>249</td>
<td>23</td>
</tr>
<tr>
<td>Baggensfjärden</td>
<td>173</td>
<td>20</td>
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</table>
Nutrient loads to the Stockholm Archipelago

Inner, Intermediate, Outer archipelago
Results, retention of N and P
t yr$^{-1}$
Results, area specific retention

![Area specific P retention](image1)

![Area specific N retention](image2)
The coastal filter

At least 65% and 72% of the supplied P and N, respectively, from land and atmosphere were retained in the Stockholm archipelago.
Nutrient Scenario

- Forcing from year 2010
- Spin-up period for 45 years

New run
- 20% decreased N-load
- 12% decreased P-load
Nutrient Scenario

The graph shows the filter efficiency (%) over the years for both Nitrogen (N) and Phosphorus (P). It indicates that the filter efficiency increases over time, with Nitrogen reaching a higher efficiency than Phosphorus by the end of the 50-year period.
Conclusions

- The Stockholm archipelago works as a filter for the land loads of nutrients.
- There is an export of nutrients from the coast to the outer sea during the period 1990-2012.
- The filter efficiency is dependent on the spatial dimensions of the coastal area.
- The pools of nutrients in the water and in the sediment changes with nutrient loads and therefore
- the time aspect needs to be taken into account for the balance between nutrient loads and nutrient pools.
Thank you!

Processes/Characteristics affecting the retention

P filter efficiency

N filter efficiency

Billen et al., 2011; Hayn et al., 2014; Nixon et al., 1996
SCM retention calculations along the swedish coast

Retention per area unit:
Permanent sinks and temporary storage.
SCM retention calculations along the swedish coast

Nutrient filter: The retained fraction of land load
Model system and study site
<table>
<thead>
<tr>
<th>Unit</th>
<th>Average Units</th>
<th>Average obs</th>
<th>Average S-HYPE</th>
<th>r</th>
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</thead>
<tbody>
<tr>
<td>$Q_F$</td>
<td>$10^6 \text{ m}^3 \text{ month}^{-1}$</td>
<td>421</td>
<td>422</td>
<td>0.94</td>
</tr>
<tr>
<td>TN</td>
<td>t month$^{-1}$</td>
<td>270</td>
<td>271</td>
<td>0.93</td>
</tr>
<tr>
<td>DIN</td>
<td>t month$^{-1}$</td>
<td>83</td>
<td>76</td>
<td>0.86</td>
</tr>
<tr>
<td>TP</td>
<td>t month$^{-1}$</td>
<td>13</td>
<td>11</td>
<td>0.87</td>
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<tr>
<td>DIP</td>
<td>t month$^{-1}$</td>
<td>5.7</td>
<td>5.7</td>
<td>0.79</td>
</tr>
</tbody>
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Evaluation, river forcing

![Graph showing river forcing comparisons between observed (SMHI/SLU) and S-HYPE models over years 1990 to 2010. The graphs display time series of various river forcing parameters such as Q_F (10^6 m^3 month^-1), TN (ton month^-1), DIN (ton month^-1), TP (ton month^-1), and DIP (ton month^-1).]
Evaluation, model results

The combined model skills for all variables are shown by the purple cross.

Variables within:
- the inner half circle are considered to be good
- between the two half circles are acceptable
- variables outside the circles are not well captured.

\[
r = \frac{\sum_{i=1}^{n} (P_i - \bar{P})(O_i - \bar{O})}{\pm \sqrt{\sum_{i=1}^{n} (P_i - \bar{P})^2 \sum_{i=1}^{n} (O_i - \bar{O})^2}}
\]

\[
C = \sum_{i=1}^{n} \frac{|P_i - O_i|}{sd(O_i)}
\]

for all variables are shown by the purple cross.
The combined model skills for all variables are shown by the purple cross.

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Evaluation, model results, 1990-2012

\[
C = \frac{\sum_{i=1}^{n} \left| P_i - O_i \right|}{sd(O_i)} \frac{\sum_{i=1}^{n} (P_i - \bar{P})(O_i - \bar{O})}{\sqrt{\sum_{i=1}^{n} (P_i - \bar{P})^2 \sum_{i=1}^{n} (O_i - \bar{O})^2}}
\]
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Evaluation, model results, 1990-2012

Strömmen (G)

(1-r)

Depth (m)

DIN (µmol L^{-1})

DIP (µmol L^{-1})

C

Temp (°C)

DIN (µmol L^{-1})

DIP (µmol L^{-1})

O_2 (ml L^{-1})

Month

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Obs. raw data
Obs. summer
SCM summer
Obs. winter
SCM winter

Obs raw data
Range used for statistics
Obs
SCM

Surface

Surface

Bottom