Runoff, Nutrient Loads and Freshwater Ecology in a changing Climate in Denmark: What can we learn from historical data and model scenarios?

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Can the future be found looking in a mirror?
Danish climate 2100 - spatial analogs?

Figure 8: Evolution des degrés moyens constatés à la récolte en Alsace pour le rendement. Source: CIVA. Le gain moyen est de 0.08 °C vol. par an.

Duchêne and Schneider 2004
Observed changes in annual precipitation and the contribution of heavy rainfall to total precipitation 1961–2006

Source: EEA, 2008. The climate dataset is from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl).
Trend in average precipitation and runoff in two Danish rivers

Precipitation – Denmark

River Skjern – West

River Tude – East
Trends in annual runoff in 18 Danish rivers during the period 1925-2000
Monthly trends in runoff in 10 Danish streams – 1920-2000
IGLOO project results changes 1950-2007:

Hansen et al., 2009
Max. discharge

Min. discharge
We are already adapting to extreme weather conditions!
Where are we going?

From IGLOO project report – Hansen et al., 2009
Predicted change in precipitation over Europe (1961-90 to 2071-2100)
Scenario A2– HIRHAM regional model

% increase in runoff

- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- >30
Projections for future runoff in Danish catchments – HIRHAM A2 scenario – control: 1961-90; Scenario: 2071-2100
Comparison of recent trends and A2 scenario trends for Denmark

<table>
<thead>
<tr>
<th></th>
<th>Recent trends 1950-2010</th>
<th>HIRHAM A2 scenario 1961-90 to 2071-2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>0.9 °C</td>
<td>3.2 °C</td>
</tr>
<tr>
<td>Precipitation</td>
<td>100 mm</td>
<td>77 mm</td>
</tr>
<tr>
<td>Runoff</td>
<td>70 mm</td>
<td>58 mm</td>
</tr>
</tbody>
</table>
Can we expect more extremes in floodings and drought periods in Danish streams?
Number of days with floodings per year increases with 50% from control period to scenario period (NAM-MIKE11 model predictions: Gjern river, Jutland)

\[ R^2 = 0.856 \]

W.B. = -6%

**Control** 34

**Scenario** 51
Increasing temperatures and water shortage will be a major threat for ecosystems.
We predicts a doubling of number of days with drying out in the small brook Ølholm Bæk from control (1961-1990) to scenario (2071-2100) in an A2 emission scenario

<table>
<thead>
<tr>
<th>Ølholm brook</th>
<th>Number of years</th>
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<tbody>
<tr>
<td>Number of days per year with drying out</td>
<td>Control periode (1961-1990)</td>
</tr>
<tr>
<td>0-10</td>
<td>13</td>
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<tr>
<td>10-20</td>
<td>12</td>
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<tr>
<td>20-30</td>
<td>3</td>
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<tr>
<td>30-40</td>
<td>2</td>
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<tr>
<td>&gt; 40</td>
<td>0</td>
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</tbody>
</table>
What happens with the sediment transport in Danish rivers?
Sediment transport is predicted to increase in streams but in lower parts of rivers highly dependent on Sea Level Rise (SLR).
Nutrients
Increases in crop yields are of course also important – but higher crop yields will demand more fertiliser/pesticide use and therefore use of more sustainable production methods.
DAISY modelled changes in nitrogen cycling in 4 agricultural Danish catchments – rootzone (< 1 m) HIRHAM A2 scenario

Grant et al., 2009
Phosphorus losses from diffuse sources to coastal waters in Denmark increases with increasing runoff

$$\text{Diffuse TP}_{\text{loss}} = 6.8 \cdot Q - 540; R^2 = 0.97 - 1990-2008$$

Windolf et al., 2010
Total nitrogen losses from diffuse sources to Danish coastal waters increases with increasing runoff – relationship has changed due to the effect of Action Plans.

Diffuse TN\textsubscript{loss} = 0.232 \times Q - 17.4; R^2 = 0.91.

For the period 2000-2008

Windolf et al., 2010
Nitrogen and phosphorus losses is predicted to increase from baseline (1961-1990) to scenario period (2071-2100) – HIRHAM A2

Increase in runoff (%)  Increase in N loading (%)  Increase in P loading (%)

Søndergaard et al., 2006 Vand og Vejr om 100 år
Two ways of predicting changes in diffuse nutrient losses to marine waters in Denmark

<table>
<thead>
<tr>
<th>Predicted change with assumed runoff trends as modelled in HIRHAM A2 scenario</th>
<th>Total N Tonnes (%)</th>
<th>Total P Tonnes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,400 (23 %)</td>
<td>400 (25%)</td>
<td></td>
</tr>
<tr>
<td>Predicted change with runoff trends as last 60 years + A2 HIRHAM</td>
<td>29,700 (51 %)</td>
<td>870 (52 %)</td>
</tr>
</tbody>
</table>
Ecological impacts - indicators

- Phytoplankton
- Macrophytes
- Macroinvertebrates
- Fish
Model for recruitment of juvenile trout against precipitation after emergence in a Danish brook based on 13 years of observations
Combined increase in temperature and increased precipitation in egg period for trout reduces the recruitment of juvenile trouts with nearly 50%

Data from Bisballe Bæk (from Lobón-Cerviá & Mortensen, 2005)

<table>
<thead>
<tr>
<th>Emergence date</th>
<th>Mean monthly precipitation in April from 1974–1987 (mm)</th>
<th>Mean recruitment from 1974–1987 (ind m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 April</td>
<td>39.1</td>
<td>4.33</td>
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Data from modelling

<table>
<thead>
<tr>
<th>Temperature scenario</th>
<th>Emergence date</th>
<th>Mean monthly precipitation one month after emergence from the period 2071–2100 (mm)</th>
<th>Recruitment (ind m$^{-2}$)</th>
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<tbody>
<tr>
<td>No increase</td>
<td>1 April</td>
<td>35.8</td>
<td>3.07</td>
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<tr>
<td>0.8</td>
<td>16 March</td>
<td>47.3</td>
<td>2.42</td>
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<td>1</td>
<td>12 March</td>
<td>49.2</td>
<td>2.34</td>
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<td>2</td>
<td>28 February</td>
<td>51.1</td>
<td>2.26</td>
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Multiple regression 250 lakes – 800 lake years
log(algae biomass) = log(TP) + log(TN) + log(mean depth) + log(water temp) – data from August only (late summer)

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<tr>
<th>Slope</th>
<th>Chlorophyll a</th>
<th>Phycoplankton</th>
<th>Diatoms</th>
<th>Greens</th>
<th>Cyanophytes</th>
<th>N-fixing cyanophytes</th>
<th>Non N-fixing cyanophytes</th>
<th>Dinophytes</th>
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<td>3.02 ± 0.85</td>
<td>3.68 ± 0.88</td>
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TP, TN, Depth, Water temperature
Adaptation tools – lake restoration
Adaptation tools – river restoration
Adaptation tools – wetland restoration

Skjern Å: 2200 ha

Bølling Sø: 375 ha + 375 ha meadow
Thank you for your attention!