Ecological effects of re-meandering lowland streams and use of restoration in river basin management plans: Experiences from Danish case studies

Hans Thodsen
Department of Freshwater Ecology, National Environmental Research Institute (NERI), University of Aarhus, Silkeborg
Ecological effect documentation following re-meandering of Danish rivers: an overview

Hans Thodsen, Brian Kronvang, Esben Kristensen, Jens Skriver, Peter Wiberg-Larsen and Annette Bastrup-Pedersen

HATH@DMU.DK

Outline

1. Dimensions and goals in river restoration?

2. River restoration in Denmark – a history of a nice sequence of Governmental Actions?

3. River re-meandering in Denmark - projects and outcomes?

4. Can we extract a new learning from 19 years of ecological effect monitoring of an active restoration (re-meandering) of the River Gelså, Denmark and an upstream passive restored reach (ceased river maintenance)?

5. WFD mapping of watercourses at risk – pressures and river types – the Pilot River Odense, Denmark.

important goals with river restoration

1. Clean water (point sources)
2. Secure connectivity
3. Improve fluvial morphology
4. Enhance biodiversity - plants, fish (salmon, houting), macroinvertebrates, birds, otter, beavers, etc.
5. Self-purification - less nutrients through self-purification in rivers and wetlands
6. Improve flood protection
7. Dampen Climate Change induced temperature fluctuations
8. Attractive recreational areas

The history of river restoration in Denmark

1. Point sources – treatment
2. River restoration – removing barriers
3. River restoration – spawning grounds
4. River hydromorphology - remeandering
5. Change in river maintenance - bioengineering weed cutting
6. River re-meandering – wetland restoration
7. Cease of river maintenance - stop weed cutting and dredging in channels

Monitoring concentration of BOD$_5$ in Danish streams - 1975-2003 – Treatment worked and this is a prerequisite before starting any river restoration!

River re-meandering and/or wetland restoration from 1998 – DK in the forefront

River Skjern
2200 hectares 34 mill. Euro

Lake Belling
Area: 375 ha + 375 ha meadow

Danish Governmental Decision:
Second Action Plan on the Aquatic Environment
3000 ha lakes and 4000 ha wetlands restored from 1998-2006
Measuring rates of nitrogen removal in restored wetlands
Governmental funding for 1 year post monitoring of nutrients mass-
balance approach
It works!

<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Area (ha)</th>
<th>Measured N-removal + changed land use (kg N ha⁻¹ yr⁻¹)</th>
<th>Estimated N-removal (kg N ha⁻¹ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egebjerg enge¹</td>
<td>34</td>
<td>53</td>
<td>200</td>
</tr>
<tr>
<td>Egebjerg enge²</td>
<td></td>
<td>72-688</td>
<td>200</td>
</tr>
<tr>
<td>Hellegård å</td>
<td>66</td>
<td>1</td>
<td>280</td>
</tr>
<tr>
<td>Kappel¹</td>
<td>28</td>
<td>14</td>
<td>140</td>
</tr>
<tr>
<td>Geddebaakken⁴</td>
<td>39</td>
<td>90</td>
<td>215</td>
</tr>
<tr>
<td>Høne Mølleå</td>
<td>14</td>
<td>220</td>
<td>200</td>
</tr>
<tr>
<td>Karlsømosen</td>
<td>63</td>
<td>337</td>
<td>270</td>
</tr>
<tr>
<td>Lindauer</td>
<td>84</td>
<td>191</td>
<td>235</td>
</tr>
<tr>
<td>Snaremose &quot;Sø&quot;³</td>
<td>34</td>
<td>256</td>
<td>200</td>
</tr>
<tr>
<td>Frisvad M.ø⁵</td>
<td>39</td>
<td>(95)</td>
<td>279</td>
</tr>
<tr>
<td>Ulleruplund</td>
<td>13</td>
<td>133</td>
<td>210</td>
</tr>
<tr>
<td>Gammelby Bæk</td>
<td>27</td>
<td>83</td>
<td>343</td>
</tr>
<tr>
<td>Nøbbel Å</td>
<td>64</td>
<td>165</td>
<td>300</td>
</tr>
<tr>
<td>Hjortup Bæk</td>
<td>31</td>
<td>170</td>
<td>475</td>
</tr>
</tbody>
</table>

River re-meandering in Denmark

- Many larger projects have been carried out for more than 25 years and with a high cost - but what have we achieved?

- Documentation of ecological effects do not correspond to the large number of projects carried out - but we do have - at least - fragments of knowledge

Total = 109 projects
Experiences from monitoring river re-meandering in Denmark.

Short-term effects - well described
- Initial increased erosion and transport of sediments and nutrients.
- Initial reduction in number of taxa and especially density of plants and animals.
- Recovery very different between projects, reflecting placement in river continuum, climatic conditions during the restoration period and site specific conditions such as hydrology, geomorphology and ecological dispersal potential.

Experiences/2
- Longer - or long-term effects

The few studies (primarily River Gelså) showed no or very limited - shorter term effects on the biota from 1989-1997
Friberg et al., 1998 and 2001
The River Gelså Case

The River Gelså re-meandering case study – 19th years of experience

- In 1989 the 1,300 m channelized River Gelså (6 m in width) was restored to a new 1,800 m meandering reach.
- At the same time all stream maintenance ceased regarding annual weed cuttings and dredging of the channel.
- A monitoring of the ecological conditions started before the re-meandering in 1989 on five reaches of the restored reach and on two upstream control reaches (a Before-After Control-Impact - BACI design was implemented).
- Stream maintenance was also ceased on the upstream control reach – so what was intended a true control became an example of a passive restored reach.
Brown Trout Habitat Quality

improved from 1997 to 2008 on the active re-meandered reach but only to a level being comparable to the habitat quality on the passive restored reach (ceased river maintenance)

ASPT (Average Score Per Taxa) *macroinvertebrate Index* increased on the active restored reach as opposed to the passive restored reach
Increase in the **total richness of plant species** in the restored reach of River Gelså. Changes in plant community towards more sensitive and rare species due to cease in weed cutting on both active and passive restored reaches in river Gelså.

<table>
<thead>
<tr>
<th></th>
<th>Before restoration</th>
<th>1 year after</th>
<th>2 years after</th>
<th>13 years after</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total richness</td>
<td>19</td>
<td>23</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td>Richness in submerged and amphibious species</td>
<td>14</td>
<td>12</td>
<td>18</td>
<td>17</td>
</tr>
</tbody>
</table>

Possible development in the ecological diversity following different river management methods:

- **Active restoration - re-meandering**
- **Passive restoration – ceased maintenance**
- **Harsh river maintenance**

![Graph showing ecological diversity over time](chart.png)

*Years after restoration*
Costs of three main types of river restoration measures being implemented in Denmark

1. Hard Active Restoration involving re-meandering with much planning and use of heavy machinery: (15,000-150,000 EURO per km river channel depending greatly on size of channel).

2. Passive Restoration through ceased river maintenance earns money: (1,000-2,000 EURO per km river channel).

3. Soft Active Restoration involving ceased river maintenance and input of stones and wood to the river channel: (2,000-20,000 EURO per km river channel).

The Pilot River Odense Case
Pressures on watercourses in the River Odense Basin being at risk for not fulfilling the WFD objectives in 2015.

<table>
<thead>
<tr>
<th>Pressure Type</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Direct pressures on biota from migration obstructions, etc.</td>
<td>69.3%</td>
</tr>
<tr>
<td>Morphological pressures</td>
<td>77.0%</td>
</tr>
<tr>
<td>Hydrological pressures</td>
<td>0.5%</td>
</tr>
<tr>
<td>Water abstraction</td>
<td>2.2%</td>
</tr>
<tr>
<td>Harmful substances</td>
<td>22.6%</td>
</tr>
<tr>
<td>Organic matter and nutrient pollution</td>
<td></td>
</tr>
</tbody>
</table>

Restoring the ecology of smaller streams is most cost-effective (more km per EURO) and (more ecological value per EURO)
- streams are the heart of river systems

- The river network in Europe consists of about 12 million kilometres of rivers and at least 80% of them are small (1st and 2nd order streams).
- Such rivers are commonly known as headwaters, creeks, streams or brooks.
- From an ecological point of view they are extremely valuable by providing habitats for a wide range of plants and animals and their colonization potential for the river continuum are invaluable.
How to prioritize river restoration measures - Pilot River Odense case study

<table>
<thead>
<tr>
<th></th>
<th>Type 1 (1-2 order)</th>
<th>Type II (3-4 order)</th>
<th>Type III (&gt; 4th order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for restoration (km)</td>
<td>155</td>
<td>54</td>
<td>18</td>
</tr>
<tr>
<td>Soft active restoration (km) (Boulders, Wood &amp; Green corridors)</td>
<td>155</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive restoration – cease river maintenance (km)</td>
<td>54</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Culverted stream channels (km)</td>
<td>236</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hard active restoration - re-opening of culverted reaches</td>
<td>236</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Take home messages

- Start with restoring water quality and river connectivity
- Start restoring from upstream in your catchment – the headwaters - and move downstream
- Use passive restoration (cease river maintenance) and combine with soft active measures where ever applicable – most cost-effective
- Don’t fix the river banks, unless it necessary
- Monitor a selection of your restoration projects using targeted indicators
- **If you are using active restoration measures** await starting monitoring until after the first couple of years (disturbance from heavy machinery) and continue instead for a longer period (colonization takes time)