Ecological and nutrient retention effects of river and floodplain restoration: experiences from Denmark

Brian Kronvang

and

Carl Christian Hoffmann

BKR@DMU.DK

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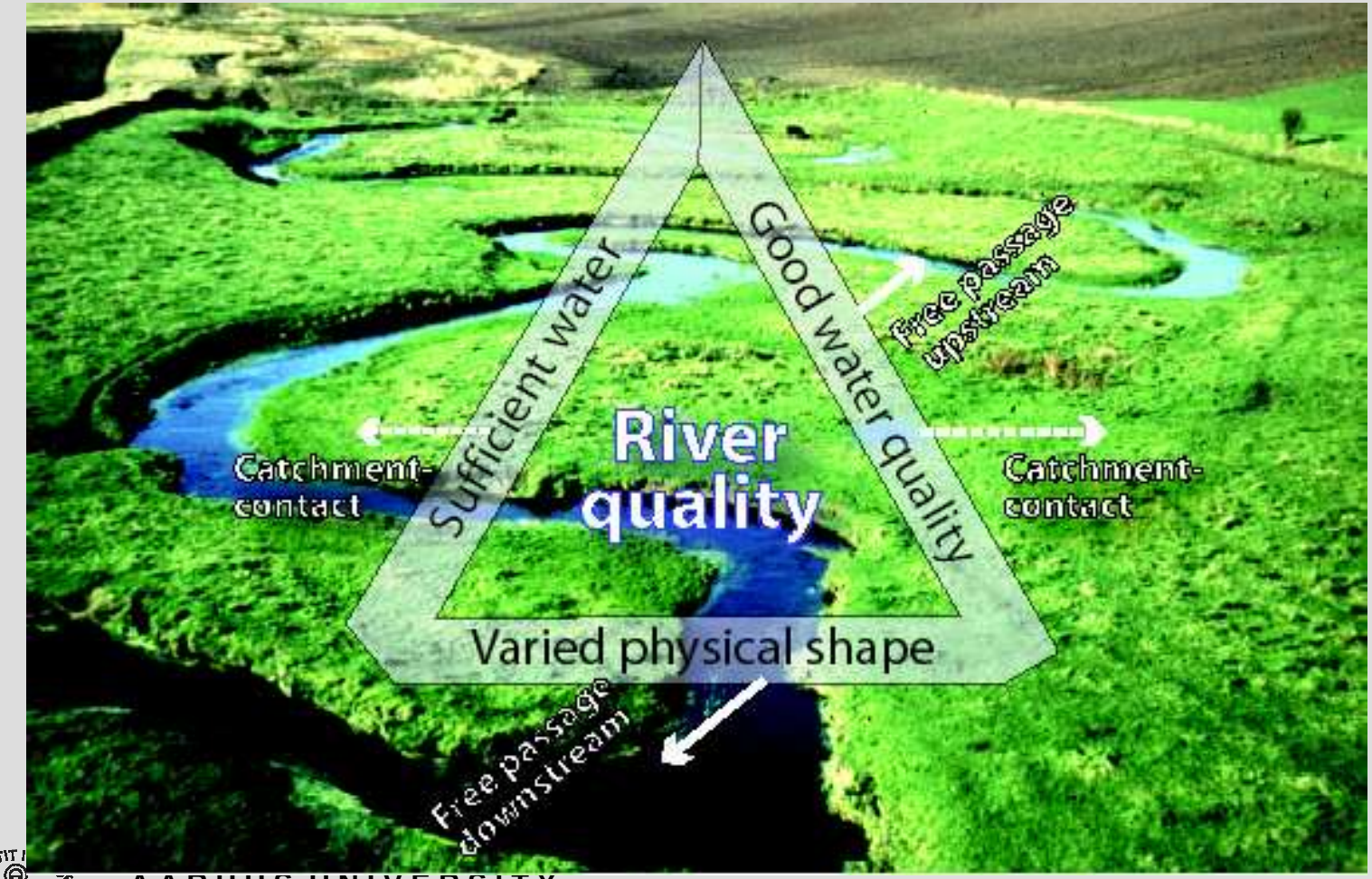
Department of Freshwater Ecology

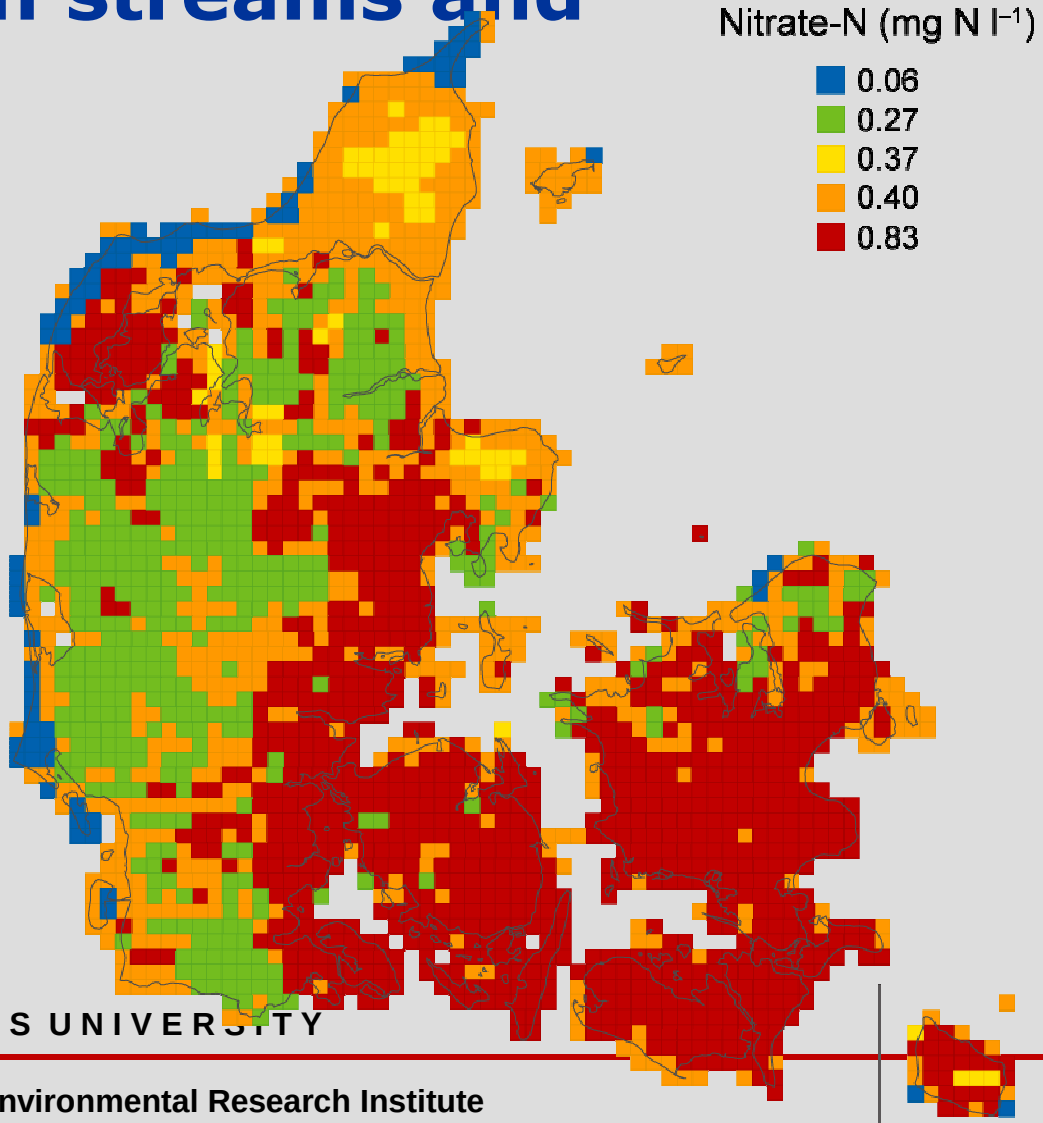
Outline

1. Dimensions and goals in river restoration.
2. River restoration in Denmark – a history of a nice sequence of Governmental Actions.
3. A new Action Plan for Green Growth in Denmark.
4. Effects of buffer zones along Danish streams.
5. Effects of wetland restoration for nutrient retention.
6. River re-meandering in Denmark - projects and outcomes ?
7. 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) ?
8. WFD mapping of watercourses at risk – pressures and river types – the Pilot River Odense, Denmark.
9. A proposal for the future use of river restoration under the Water Framework Directive – Pilot River Odense case.

Five dimensions in river quality



Background nitrate-N concentrations in Danish streams and lakes



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8 goals with river restoration

1. Clean water (point sources)
2. Secure connectivity.
3. Improve hydromorphology.
4. Enhance biodiversity – plants, fish (salmon, haunting), macroinvertebrates, birds, otter, beavers, etc
5. Cleaner water – less nutrients through self-purification in river and wetlands.
6. Improve flood protection.
7. Dampen temperature fluctuations.
8. Attractive recreation.

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7. Cease of river maintenance - stop weed cutting in channels, 10 m buffer zone

6. River re-meandering – wetland restoration

5. Change in river maintenance - bioengineering weed cutting, buffer strips

4. River hydromorphology - remeandering

3. River restoration – spawning grounds

2. River restoration – removing barriers

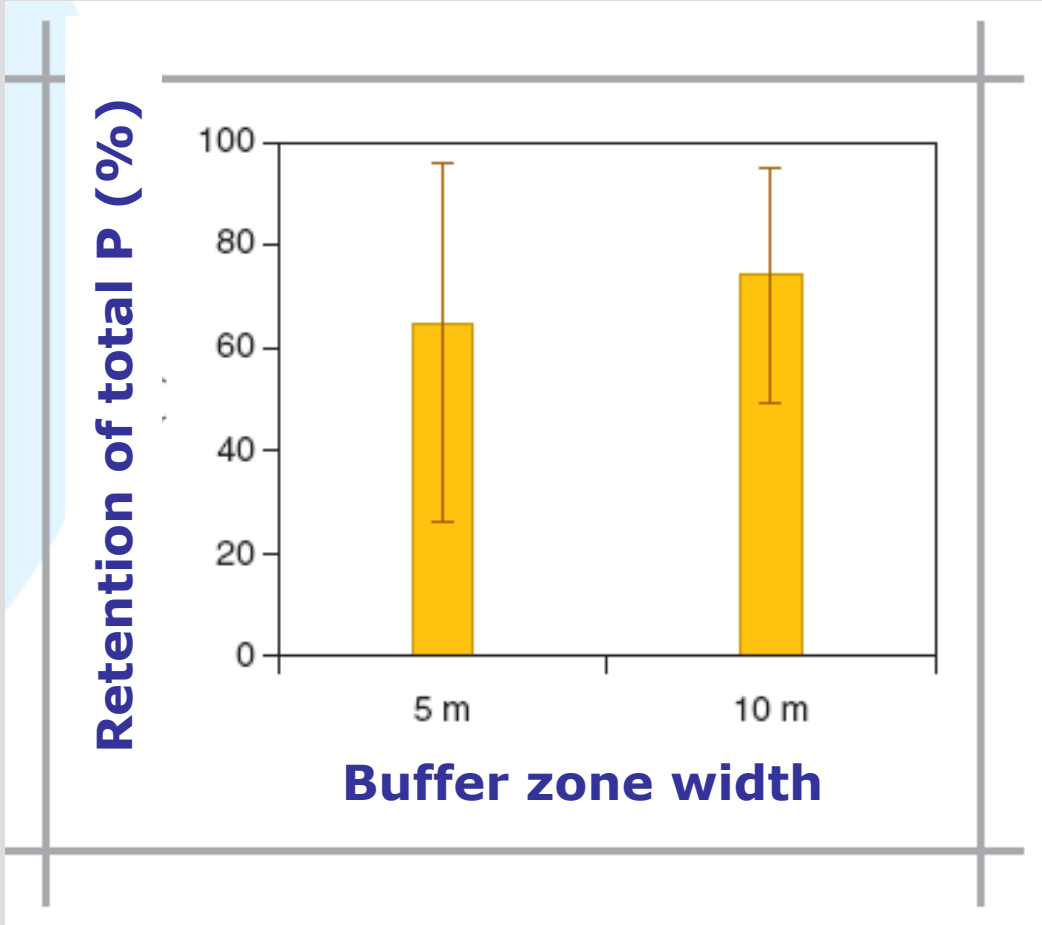
1. Point sources - treatment

1970 1982 1998 2012

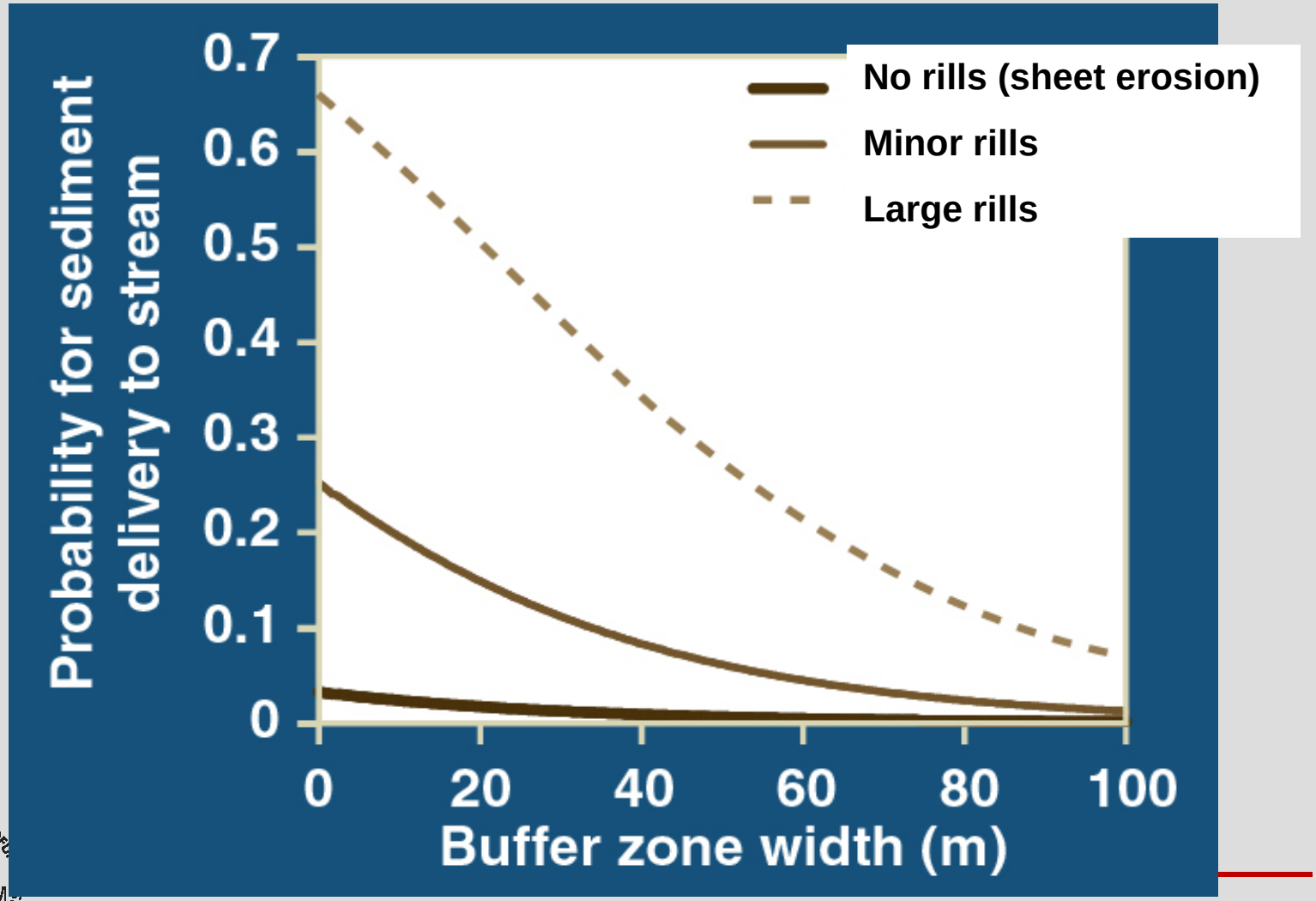
New proposal for a Danish plan for Green Growth 2015 – Danish Government April 2009

- Reduction of nitrogen loss to surface waters of 19,000 tonnes N.
- A marked based annual nitrogen quota system for trading (annual auction?) – Ready from 2012 and will have to be accepted by EU. Profit from selling quota is returned to farmers via reduced taxes.
- Extra 140,000 ha with catch crops.
- Restored wetlands on up to 10,000 ha
- Inundated floodplains on up to 3,000 ha
- Establishment of 50,000 ha of 10 m wide uncultivated buffer zones in riparian corridors along streams and around lakes before 2015 to reduce losses of P from surface runoff, bank erosion and leaching.
- River restoration along up to 7,300 km channels.

Plot studies show generally a high efficiency of buffer zones for retention of total P !

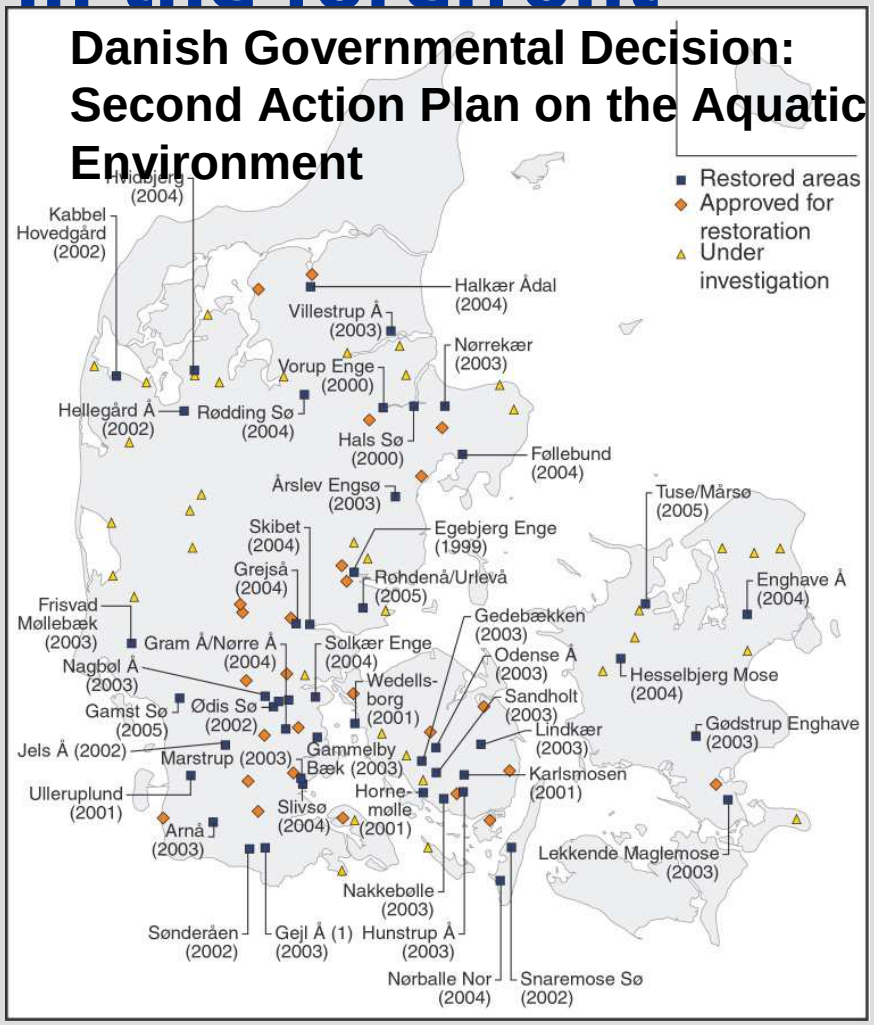


But – reality is somewhat different ! probability for fine sediment delivery from soil erosion on arable fields to streams through a buffer zone of various width – field survey of 130 fields during 3 winter periods



River re-meandering and wetland restoration – DK in the forefront

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 surely works !

Name of Project	Area ha	Measured N-removal kg N ha^{-1} yr^{-1}	Measured N-removal + changed land use kg N ha^{-1} yr^{-1}	Estimated N-removal kg N ha^{-1} yr^{-1}
Egebjerg enge[1]	34	53	53	200
Egebjerg enge[2]		72-688	72-688	200
Hellegård å	66	!	!	280
Kappel[4]	28	14	39	140
Geddebækken[4]	39	90	125	215
Horne Mølleå	14	220	255	200
Karlsmosen	63	337	372	270
Lindkær	84	191	226	235
Snaremose "Sø"[3]	34	256	291	200
Frisvad M.bæk[4]	39	(95)		279
Ulleruplund	13	133	170	210
Gammelby Bæk	27	83	105	343
Nagbøl Å	64	163	187	300
Hjarup Bæk	31	170	200	475

Nitrogen removal in surveyed lakes

	Lake area	Total area	Measured	Estimated
	ha	ha	kg N ha^{-1} $year^{-1}$ (total project area)	
Årslev Engsø	100	210	252	382
Hals sø	42	53	40	200
Nakkebølle	85	110	125	300
Skibet	26	40	125	205
Slivsø	160	203	244	440
Wedellsborg	11	27	126	234
Ødis Sø	26	40	184	230

Phosphorus

Results from the wetland monitoring programme – sometimes it works !

Wetlands	P-retention Kg P ha^{-1} yr^{-1}	%
Ulleruplund	-0.43	-88
Gammelby	-0.4	-7
Bæk	0.4	6
(different calculations)	20	75
Egebjerg Enge	0.13	6
Karlsmosen	8.1 – 9.0	53-60
Snaremose	2.6	18
Lindkær	-0.5	-11
Geddebækken	0.5	21
Nagbøl Å	0.9	11
Hjarup Bæk	12	42

Why study the interaction between river and floodplain ? More than 90% of Danish lowland streams and rivers has been regulated for draining the surrounding land for agricultural production

So, today, flooding is seldom along Danish rivers and the natural functioning of floodplains as sinks for sediment, carbon, nitrogen and phosphorus are cut off.

Photo: I. & A. Toft Andersen

125 river restoration projects where the natural hydrological interaction between river and floodplain is restored have been completed in Denmark:

Before 1990:	**5 projects**
1990-1994:	**14 projects**
1995-1998:	**25 projects**
1998-2004:	**35 projects**
2004-2005:	**35 projects**
2006-2007:	***ca.* 10 projects**
TOTAL:	***ca.* 125 projects**

River Odense, Denmark

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River restoration for creating inundations of floodplains

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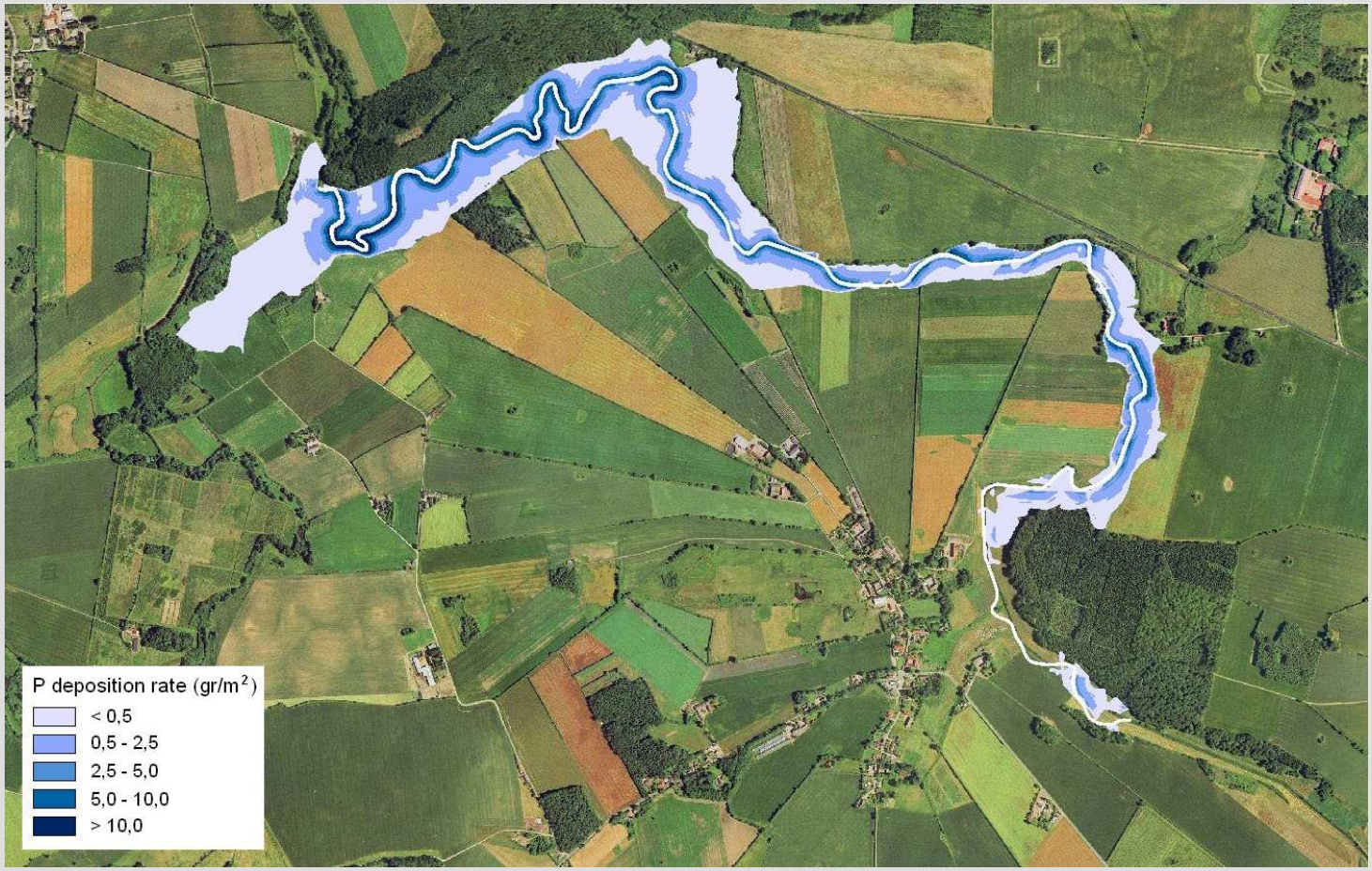
Methods

- **Water exchange**
- **Flow velocity**
- **Flow direction**
- **Daily mean discharge**
- **Interactions between river and floodplain**

- **Sedimentation**
- **Net sedimentation on 59 artificial grass mats**
- **Concentration of suspended sediment was monitored in water samples taken at 50 selected sites. Besides it was monitored automatically in the river and along a transect**

Model simulation of particulate P deposition on the 74 ha floodplain utilising a detailed topographic survey of the floodplain



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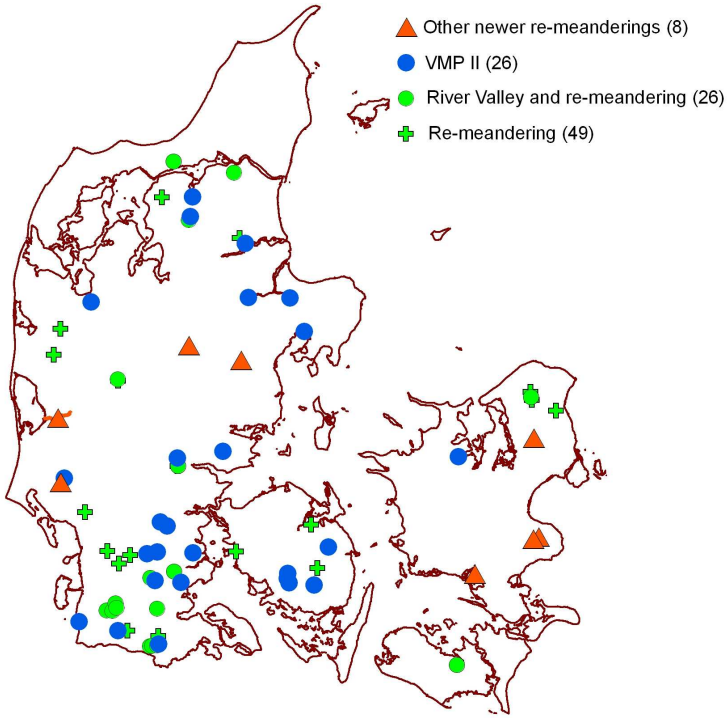
Larger river re-meandering projects conducted in Denmark:



Total = 109 projects

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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***

Experiences from monitoring river restoration in Denmark.

Short-term effects - well described

- Initial increased erosion and transport of suspended sediments, bed load and nutrients.
- Initial reduction in number of taxa and especially density of plants and animals.
- Improved physical conditions.
- Recovery within 1 to 2 years of both sediment, chemical and biological features – avoid effects monitoring 1st year after restoration.
- Recovery rate 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

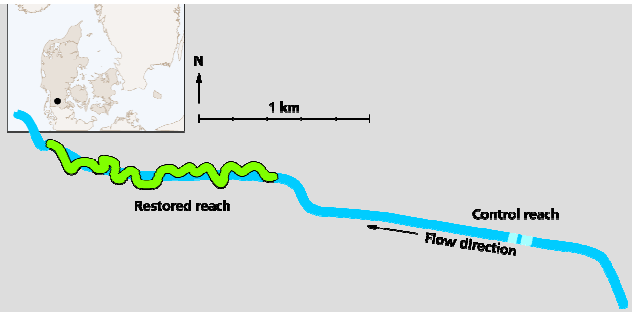
- **Longer - or long-term effects**

?

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 re-meandering case study – 19th years of experience

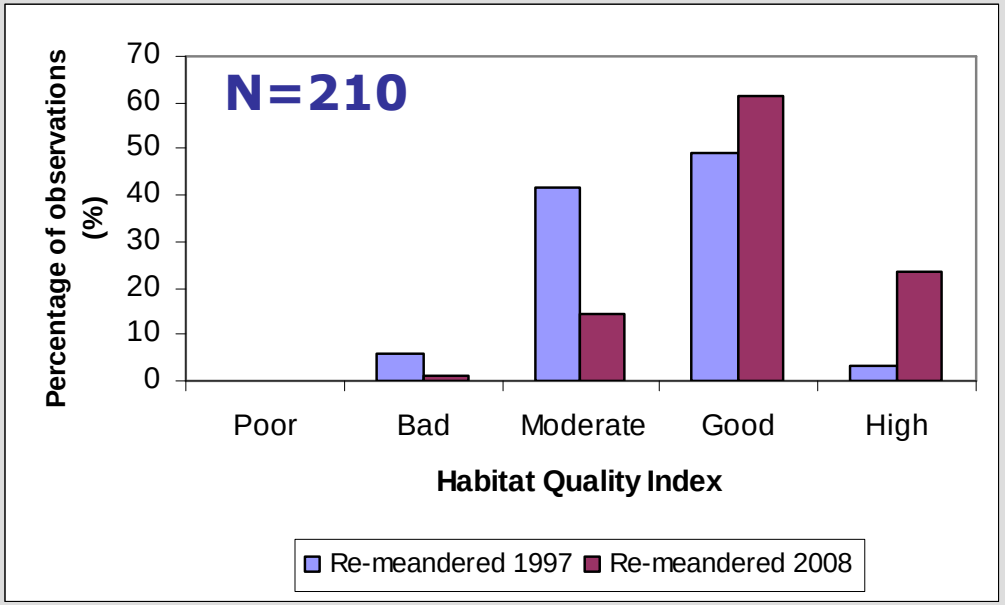


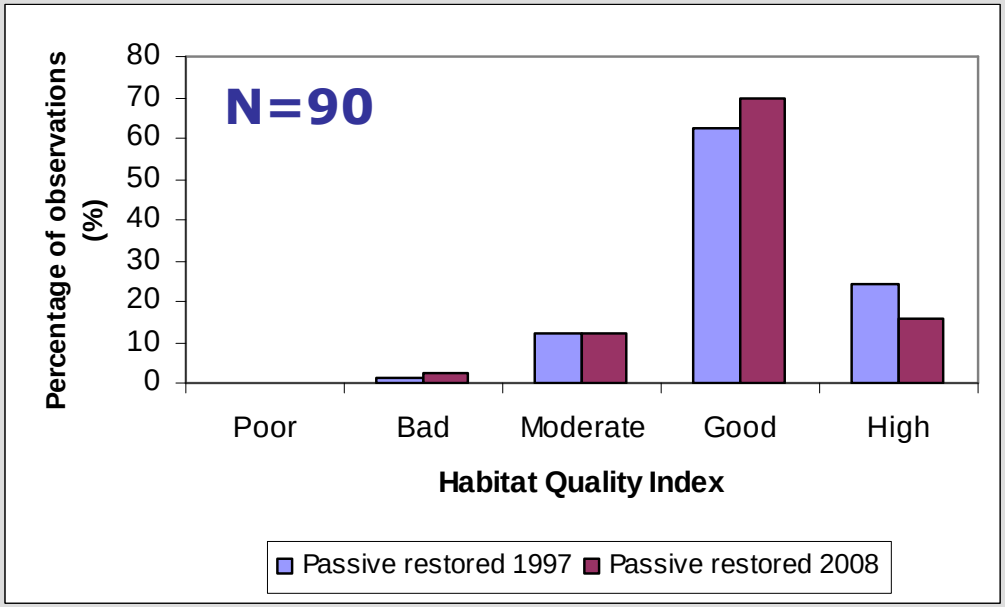
- **In 1989 the 1,300 m channelized River Gelså (6 m in width) was restored to a new 1,800 m meandering reach.**
- **At the same time all stream maintenance ceased regarding annual weed cuttings and dredging of the channel.**
- **A monitoring of the ecological conditions started before the re-meandering in 1989 on five reaches of the restored reach and on two upstream control reaches (a Before-After Control-Impact - BACI design was implemented).**
- **All 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.**

Upstream control reach – 2008

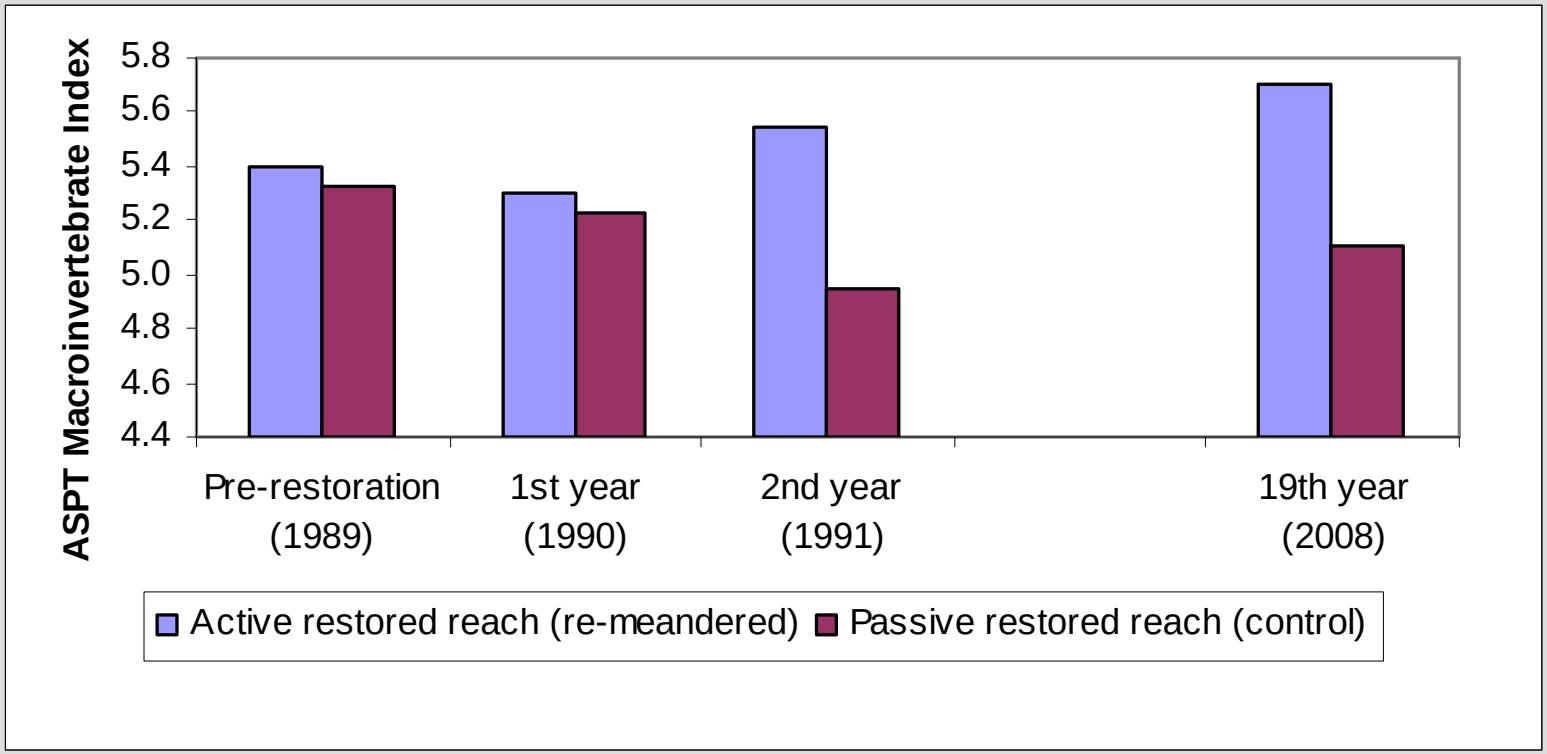
Restored reach – 2008

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)



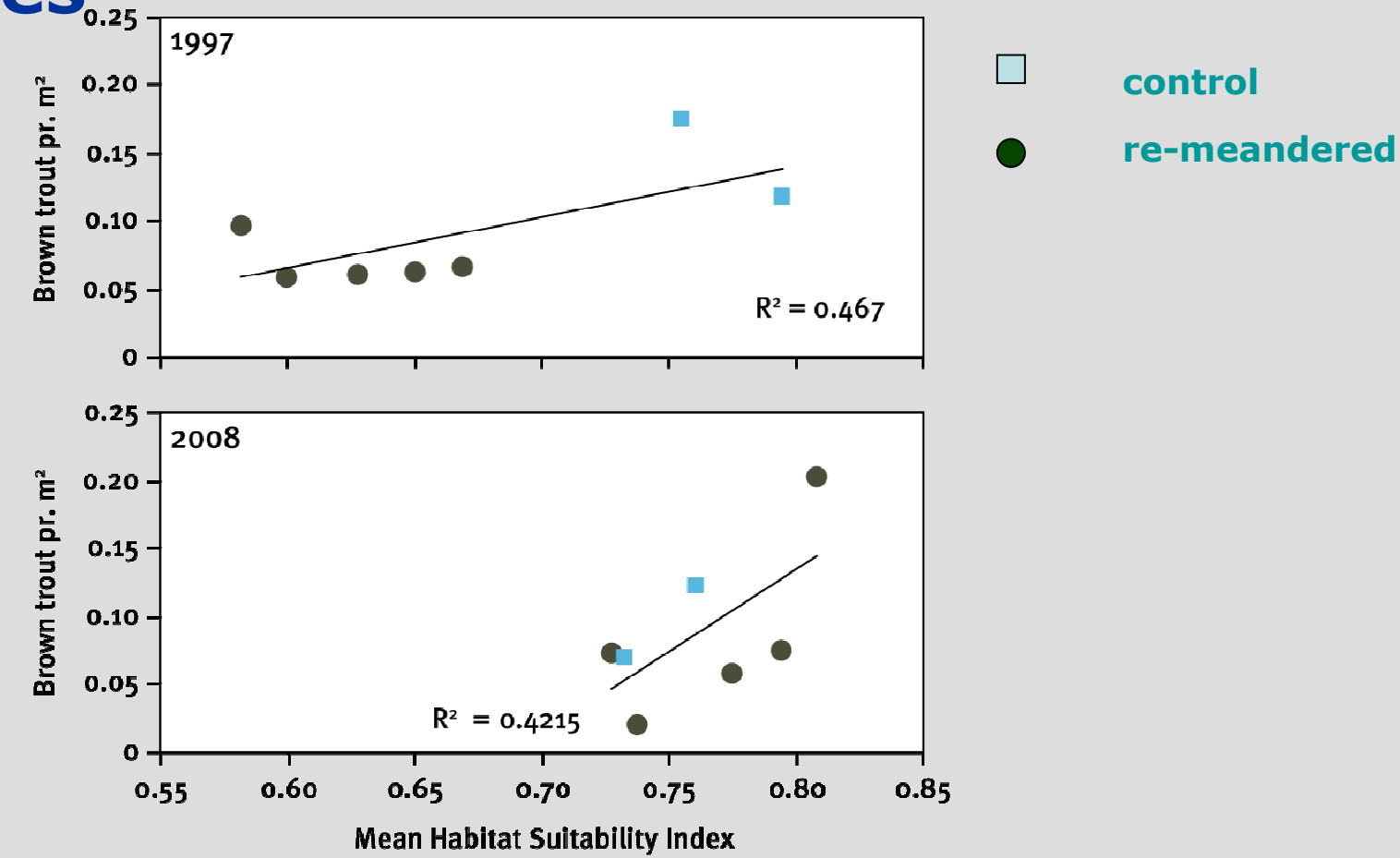


ASPT (Average Score Per Taxa) macroinvertebrate Index increased on the active restored reach as opposed to the passive restored reach



The improved habitat conditions on the active restored channel as opposed to the passive restored control channel are mainly due to the massive use of big stones for securing river meander bends from erosion !

No marked differences in Brown trout density against habitat suitability index among the control and re-meandered reaches

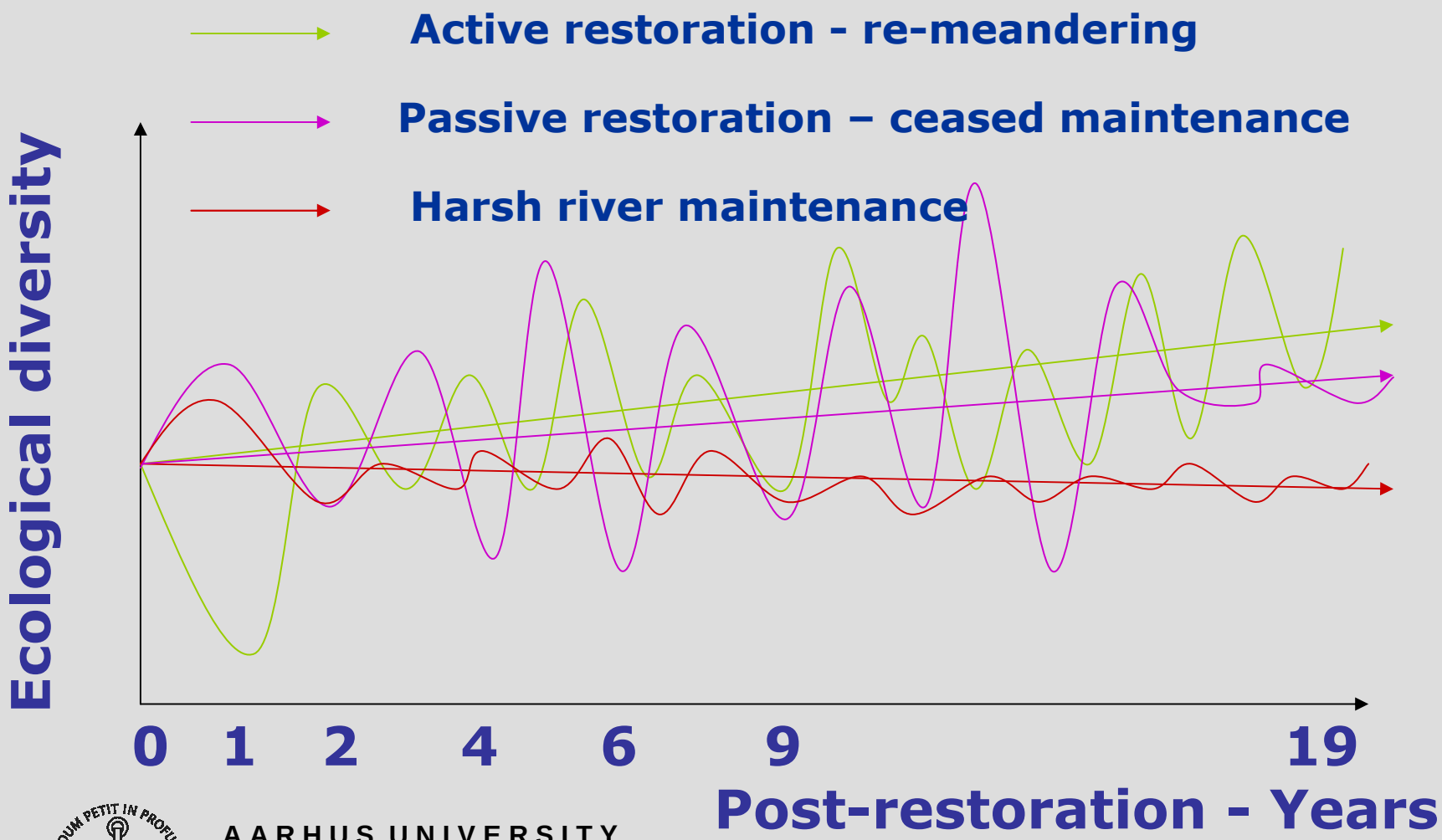


But a new invasive species was caught during electro fishing

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 .

	Before restoration	1 year after	2 years after	13 years after
Total richness	19	23	30	28
Richness in submerged and amphibious species	14	12	18	17

Possible development in the ecological diversity following different river management methods



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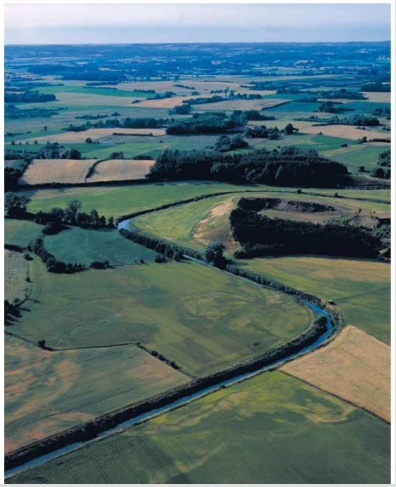
Costs of three main types of river restoration measures being implemented in Denmark

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).**

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



Direct pressures on biota from obstructions, etc.	Morpholog-ical pressures	Hydrological pressures Water abstraction	Harmfull substances	Organic and nutrient pollution
69.3 %	**77.0 %**	**0.5 %**	**2.2 %**	**22.6 %**

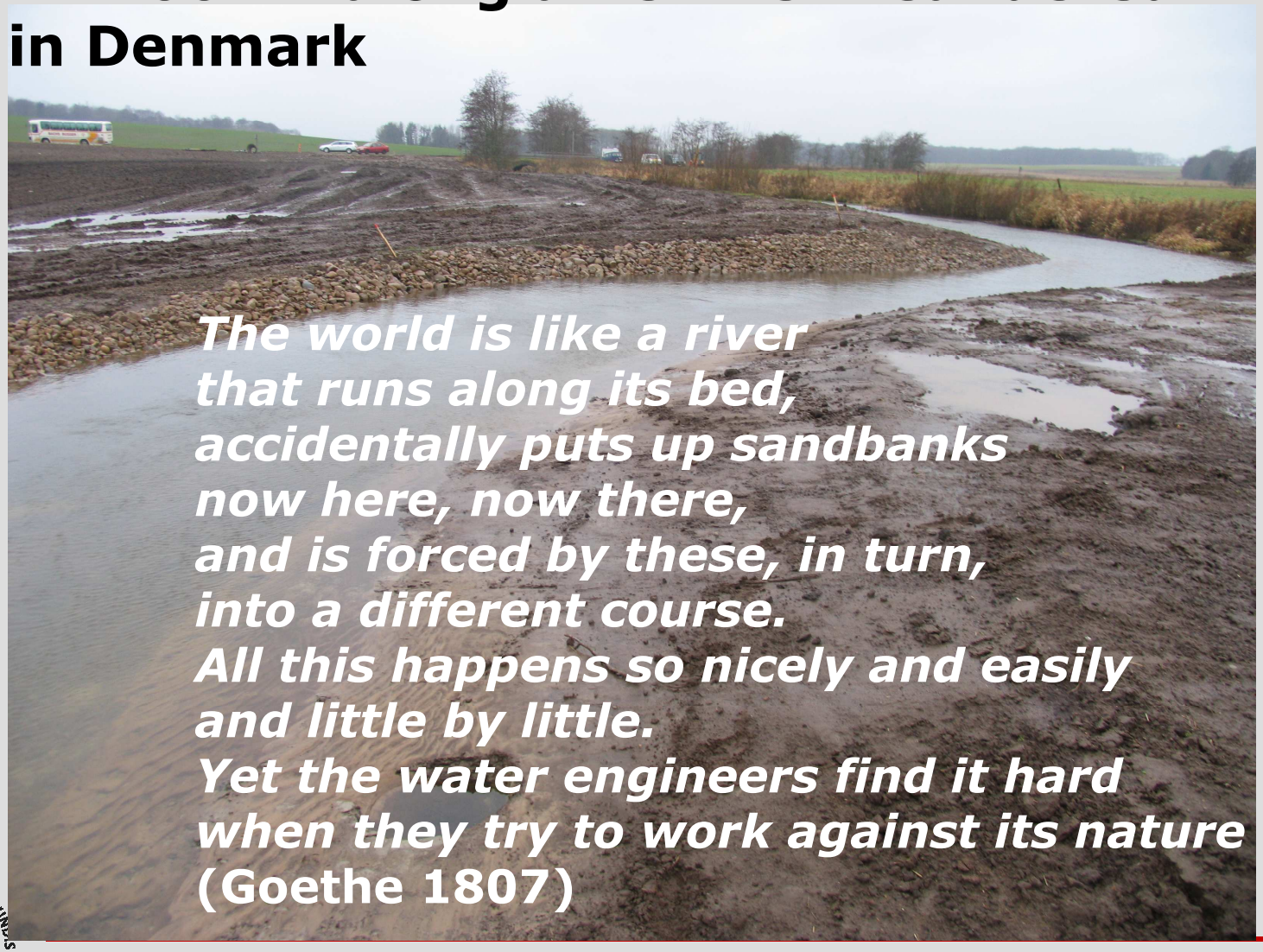
How to prioritize river restoration measures - Pilot River Odense case study

	Type 1 (1-2 order)	Type II (3-4 order)	Type III (> 4th order)
Need for restoration (km)	155	54	18
Soft active restoration (km)	155		
Passive restoration – cease river maintenance (km)		54	18
Culverted stream channels (km)	236	0	0
Hard active restoration - re-opening of culverted reaches	236	0	0

Restoration of small streams gives both more km and more ecological value for the costs - they 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.**

Hard engineering of river banks for preventing free dynamics and processes
Autumn 2007 – along a new re-meandered river in Denmark



The world is like a river
that runs along its bed,
accidentally puts up sandbanks
now here, now there,
and is forced by these, in turn,
into a different course.
All this happens so nicely and easily
and little by little.
Yet the water engineers find it hard
when they try to work against its nature
(Goethe 1807)