Re-establishing freshwater wetlands in Denmark

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Why wetland re-establishment?

Loss of wetland area (> 50% in Europe)

because of: agricultural drainage (more arable land)

urban development

afforestation

water reclamation

Streams and rivers have been heavily modified (98% physical change)

Fertilisation rates have increased → major source of nutrient to aquatic ecosystem → eutrophication

Objective: reduce nutrient input

Wetlands: have favorable condition to denitrification (High C, anoxia)

Action plans:

International: EU Water Framework Directive - water quality at 2015

Local: Danish Action Plan on the Aquatic Environment II (DAPAE-II) 1998-2006

- increasing wetland area in 16.000 ha
- restore 60.000 to 100.000 ha wetland (within two decades)
- N removal rate of 350 kg ha^{-1} $year^{-1}$

Objective:

To **compare N removal estimated** prior to **wetland re-establishment** to N removal **monitored** in surveyed wetlands.

To give a short status of the **project progress** and information about current **land-use** in the re-established wetlands.

Methods

- The parameters included in the monitoring programme are:
  - Topography and land use
  - Soil characteristics
  - Hydrology and nutrients
  - Vegetation
  - Birds

– **Topography and land use**

Use of Danish Area Information System and information about cultivation and farming practice was gathered from questionnaires

– **Soil characteristics**

– **Hydrology and nutrients**

Methods for analysis of nutrients follow Danish Standards. Association and all analyses have to be performed by authorized laboratories.

Hydrological and nutrient parameters are measured or sampled once a month for 1 year as standard

- **Vegetation**

1) To establish the influence of the re-establishment on the vegetation in the areas, a pre-monitoring of the existing vegetation is performed

2) As the response of the vegetation to re-stablishment takes place gradually over a period of years the post monitoring will not be performed until 2009 (3 years after the end of the project).

- **Birds**

Bird registrations were performed three times prior to and post the re-establishment of the areas. Two of the visits were performed in the morning and one visit was performed in the evening.

Estimation of nitrogen removal

First step is to contact the local authority which applies for money at the Danish Nature and Forest Agency to a feasibility study.

For the project to be approved the estimated nitrogen removal range must be between 200 and 500 kg N ha^{-1} $year^{-1}$.

(Estimation performed by the regional authorities according to guidelines from the Danish Nature and Forest Agency, 2003; Hoffmann et al., 2000a, 2003)

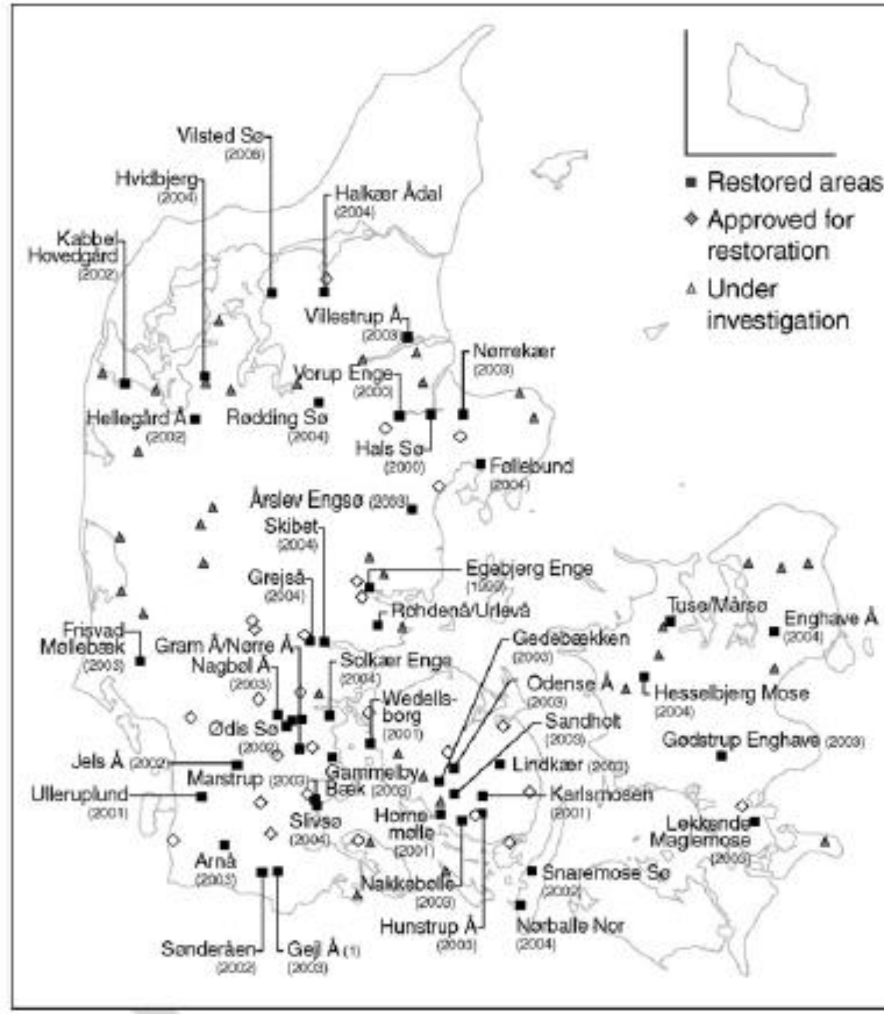
Table 1 – Total area and total estimated nitrogen removal for all types of wetland restoration projects which have been approved for restoration or which have already been carried out

Project type	Area (ha)	Nitrogen removal (kg N ha^{-1} $year^{-1}$)	Total nitrogen removal (kg N $year^{-1}$)
Shallow lakes	2985	251	750,098
Irrigation	464	293	135,998
Inundation	598	290	173,429
Irrigation + inundation	748	257	192,274
River valley projects	1905	254	485,029
Fen + wet meadow + others	129	229	29,560
All areas	6829	259	1,766,387

Project progress

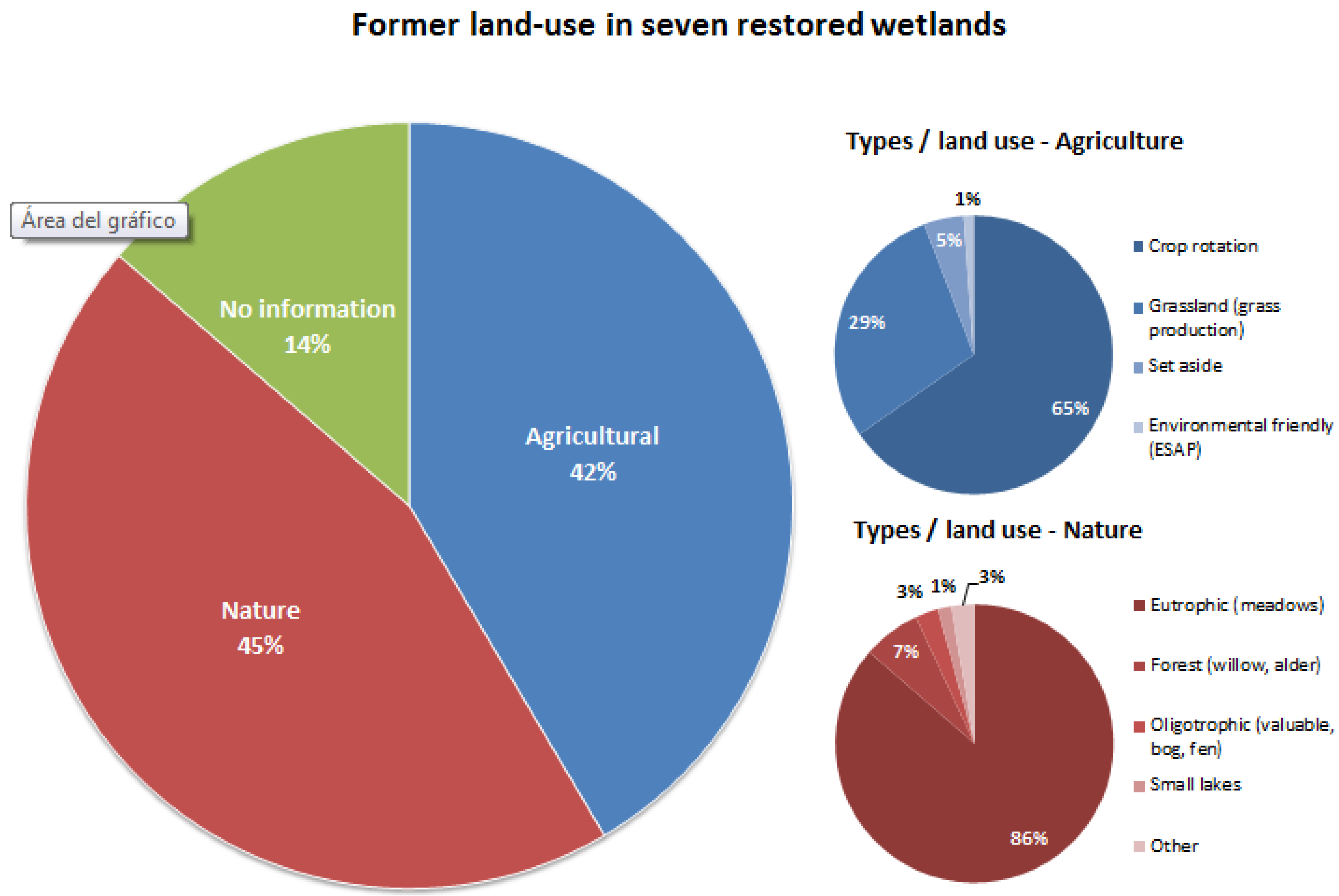
On August 2005:

- 46 projects with a total area of 3060 ha have been re-established under DAPAE-II
- 31 projects with an area of 3769 ha have been approved for implementation
- 12 preliminary projects, representing 1721 ha, are expected to be re-established
- 41 restoration projects have been abandoned



Results and discussion

Former land-use in the re-established wetlands



The natural values in the areas, as inferred from land-use and existing plant communities, were low prior to re-establishment.

Measured nitrogen removal and nitrogen load

Site	Wetland Type	Area (ha)	Measures + changed land-use (kg N ha^{-1} y^{-1})	Estimated N-removal (kg N ha-1 y-1)
Egebjerg enge a	Irrigation + Inundation	34	53	200
Egebjerg enge b	Irrigation + Inundation	34	688	200
Hellegard c	River valley, irrigation	66		280
Kappel d	Irrigation	28	39	140
Geddebaekken d	Irrigation + surface wa[illegible]	39	125	215
Horne Mollea	Irriga[illegible]n	[illegible]	[illegible]	[illegible]
Karlsmosen	Irrigatio[illegible] inundation	[illegible]	[illegible]	[illegible]
Lindker	Irrigation	[illegible]	[illegible]	[illegible]
Snaremose	Irrigation, fen	34	263	200
Prisvad Mollebak	River valley, groundwater	39	279	279
Ulleruplund	Irrigation	13	170	210

For three of the sites: Egebjerg enge, Kappel, and Geddebaekken, there are large discrepancies between the measured and estimated nitrogen removal rates

- The reduction in nitrogen leaching due to changed land-use has been included for some of the areas.

Measured nitrogen removal and nitrogen load

Site	Area (ha)	Catchment area wetland (ha)	Estimated N-load (kg N ha^{-1} wetland)	Estimated N - load from stream (kg N ha^{-1} wetland)	Changed land-use (kg N ha^{-1} wetland)	Measured N - load (kg N ha^{-1} wetland)
Egebjerg enge	34	161	104	168	-	76
Hellegard a (before restoration)	66	625	314		20	188
Hellegard a (after restoration)	66	625	314	-	20	83
Kappel	28	86	138		70	39
Geddebakken d	39	284	272		24	230
Horne Mollea	15	240	380	272	28	310
Karlsmosen	65	2140		677	35	668
Lindker d	84	916	224	224	35	297
Snaremose	34	515	401	-	25	812
Prisvad Mollebak	39	224	205	60000	23	95
Ulleruplund	13	60	173		37	198

- The reduction in nitrogen leaching due to changed land-use has been included.

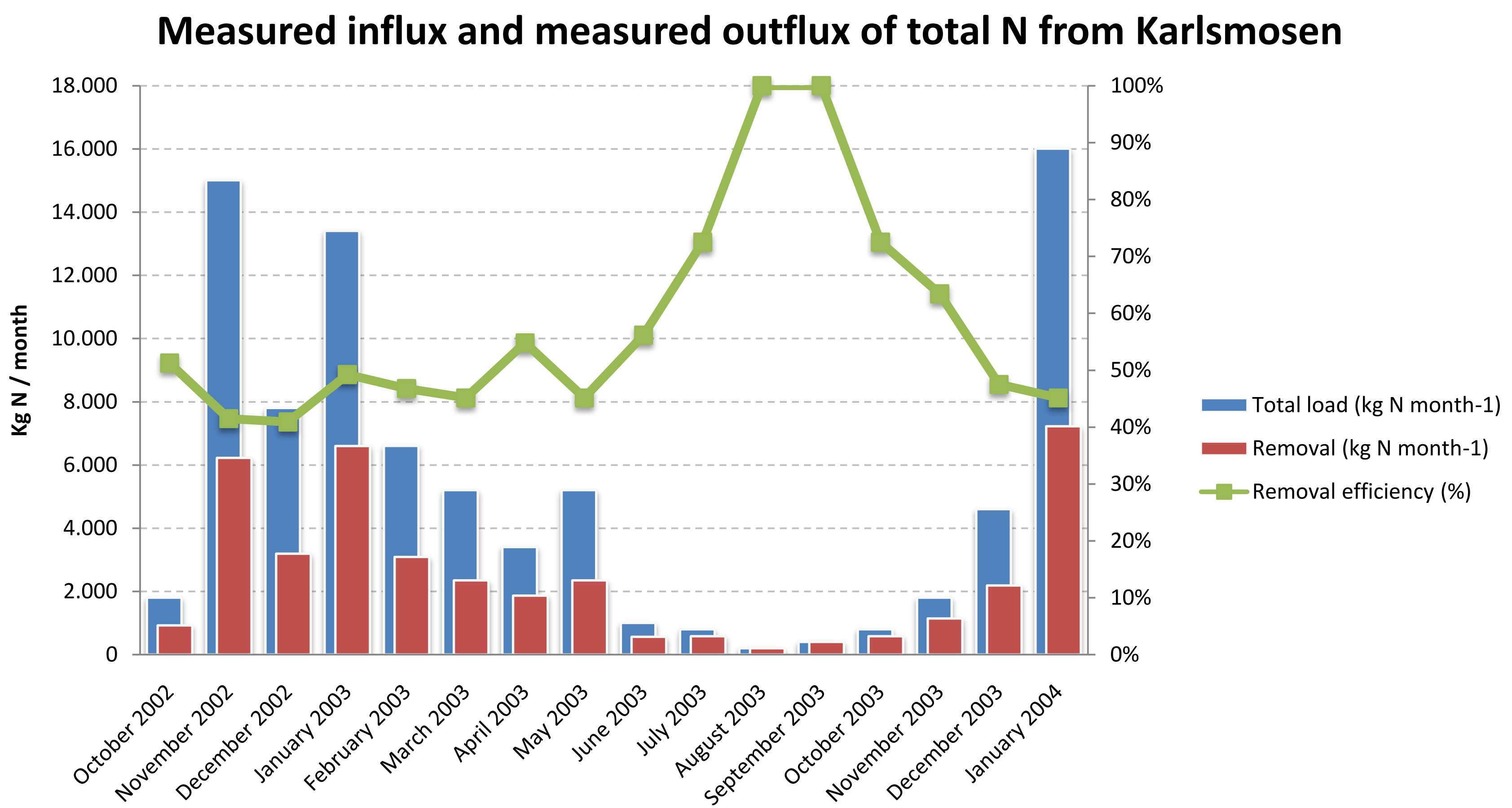
Effects of climate

- Climatic factors are of great significance for nitrogen removal rates

- Precipitation and temperature affect denitrification rates
  - Influencing the nitrogen input and the microbial metabolism.
  - Large precipitation deficits prevailed in several of the areas.

- The wetland acts as a reservoir during flooding events.
  - There is usually an incongruity between inflow and outflow from the wetland, especially when the dip is being filled with water (start of a flooding event) or is being emptied (end of a flooding event).

Effects of climate



Nitrogen removal shows little variation, being close to 50% except when then load is very small.

The variability in run-off patterns from year to year will probably also influence removal rates.

Effects of construction work

- For example, there is a dike that divides the wetland of Egebjerg Enge,
  - A part of the dike (300 m) between the wetland and the stream was removed during restoration
    of the wetland allowing the stream to inundate the wetland.

  - When the water level in the stream fluctuates frequently the exchange of water (and nitrate-nitrogen) between the wetland and the stream is big but when the water level stays the same the remaining part of dike acts as a barrier and water is trapped behind the dike.

  - The solution would be to remove the rest of the dike or make more breaches along the dike to allow water to flow from the upstream part of the wetland to the downstream part of the wetland (and stream), providing a continuous supply of water and
    nitrogen, thereby enhancing both nitrogen load and nitrogen

Conclusion

- Action Plan will not reach its original target.

  More realistic escenario: 8000 ha re-established *(16000)*

  N removal: 259 kg ha^{-1} $year^{-1}$ *(350)*

  TN reduction: 2000 tonnes *(5600)*

- Overestimation (4/9) and subestimation (3/9) of N removal rate
- N removal efficiency: 28-71 %
- Discrepancies (mesured vs. estimated N removal):

  Climatic factors

  Not optimal construction for water exchange (wetland-stream)

- Plant communities with high conservation value very restricted

Thanks!

What is the main findings of WET functioning in your paper?

Is there any doubts about the functioning of WET’s as an ecosystem services given in your paper?

Can WET’s in your opinion after reading the paper assist in reducing N and P loadings to surface waters (rivers, lakes and estuaries) – and how efficient?

If yes, to answer 3 is there any requirements about how to install and manage restored WET’s?

Can WET’s assist in giving other services to ecosystems and if yes, please mention what kind of services and the eventual requirements of restoration and management of WET’s?