Combating eutrophication in Sweden: Importance of constructed wetlands in agricultural landscapes

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The Wetland Centre at Halmstad University was commissioned by the Swedish Environmental Protection Agency and the Swedish Board of Agriculture to evaluate the effects of artificially created wetlands in Sweden between the years 1996 and 2002 with regard to nutrient retention and biodiversity. The creation of these wetlands has been financed either by Rural Development Support (RDS: Miva, Project support or Lmiva without Project support) or by Local Investment Programmes (LIP). The results are presented separately for the four different categories of constructed wetlands:

- Constructed wetlands financed by **LIP** (Local Investment Programmes) (1998-2002).
- Constructed wetlands financed by **PS** (Project Support) (2000-2002).
- Constructed wetlands financed by **Miva** (Restoration and Establishment of Wetlands and Ponds on Arable land and Semi-natural Grazing land) (1996-1999).
- Constructed wetlands financed by **Lmiva** (RDS wetlands that only get management support) (2000-2002).

The main purpose of this study has been to evaluate the extent to which wetlands created by means of these different support systems have contributed to reduced eutrophication and increased biodiversity. The purpose has not been to evaluate individual wetlands but to give an overview of the differences in efficiency between the various support systems and, to some extent, the difference in results between various geographical regions within Sweden. It has therefore been necessary to include a large number of wetlands in the evaluation, which means that extensive field sampling in the individual wetlands has not been possible. The estimates concerning nutrient retention has therefore been based on modelling, and the biodiversity has been assessed by using dragonflies (Odonata) as indicator organisms.

Information on 908 wetlands with a total area of 2860 hectares financed by RDS has been compiled and registered. In terms of area, these wetlands divide into 1815 ha financed by Miva, 920 ha financed by PS and 125 ha by Lmiva. In addition, 274 wetlands created by means of LIP, with a total area of 439 ha, have been registered. Field surveys and sampling has been conducted in more than 100 wetlands randomly selected from this register. It is mainly the results from these selected wetlands that are presented here.

Location and design of the wetlands

Depending on support system, the wetlands differ in location and design. On average, LIP and PS wetlands are situated 24 and 28 km from the sea, respectively. 28% of the LIP wetlands and 30 % of the PS wetlands are located upstream of a major lake. Miva and Lmiva wetlands are located 44 and 60 km from the sea, respectively, and more than 50 % of these wetlands are situated upstream of a major lake. About 25 % of the Miva and Lmiva wetlands receive only groundwater. When the actual wetland area (i.e. the area of maximal water table measured during the field surveys) was compared with the subsidised wetland area, it was found that in LIP and PS wetlands the actual wetland area is approximately 50 % of the subsidised area, whereas the actual wetland area constitutes about 80% of the subsidised area in Miva and Lmiva wetlands.

Nutrient retention

Modelling showed that wetlands financed by LIP achieve a higher nitrogen retention than wetlands financed by the various RDS subsidies (Fig. 1). For wetlands financed by RDS, the nitrogen retention is less than 100 kg N per ha wetland and year. This low value can to some extent be attributed to a low area-specific retention in a few very large wetlands. The nitrogen retention in wetlands financed by LIP is estimated to c. 500 kg N per ha and year. Both within LIP and RDS there are individual wetlands with a nitrogen retention of about 1000 kg N per ha and year.

Wetlands created by means of PS funding do not differ from wetlands financed by Miva or Lmiva with regard to nitrogen retention. However, the modelling showed that PS wetlands were more efficient than Miva and Lmiva wetlands in decreasing the nitrogen deposition in the sea. This can be explained by the fact that the PS wetlands, on average, are situated nearer the sea, and hence have a lower down-stream retention than the Miva and Lmiva wetlands. Regionally, the wetlands constructed in the province of Scania have a higher nitrogen retention than those in other regions in Sweden. The trends in phosphorous retention are similar to those described for nitrogen. In LIP wetlands the phosphorous retention is 4 - 12 kg P per ha and year, while the retention in the various RDS wetlands are approximately 1 kg P per ha and year.

In total, the 1940 hectares of constructed wetlands financed by Miva and Lmiva are estimated to reduce the nitrogen transportation to the sea by 35-120 tons per year depending on modelling method. For wetlands financed by PS, the estimated nitrogen reduction amounts to 31-54 tons per year (920 hectares), and for wetlands financed by LIP the reduction is estimated to 75-107 tons per year (439 hectares), depending on the modelling method.

LIP and PS wetlands have a higher percentage of arable land in their drainage area compared to wetlands financed by Miva and Lmiva. LIP wetlands are generally smaller, but have a larger drainage area, leading to a higher area specific nutrient load compared to wetlands financed by other support systems.

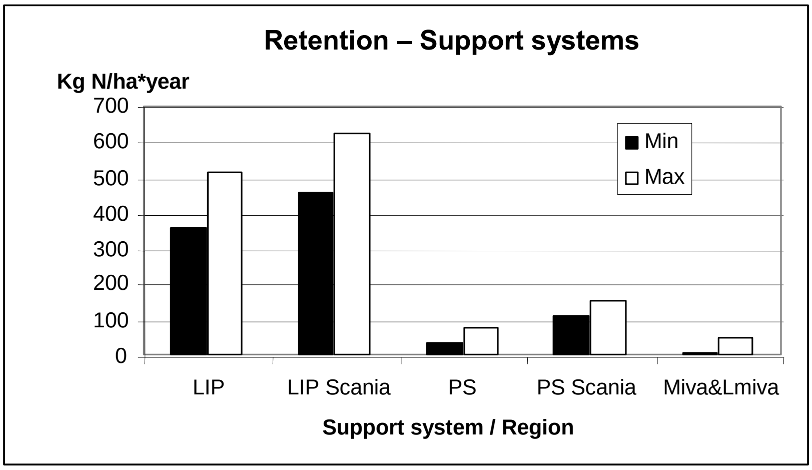

Figure 1. Differences in nitrogen retention effect (calculated as decreased nitrogen transport the sea) between different support systems. Min and max values represent different modelling methods.

Nutrient retention in storm water wetlands

The artificial storm water wetlands financed by LIP are calculated to remove 6,5 ton N, 0,9 ton P, 100 kg Pb, 500 kg Zn, 200 kg Cu, 1,6 kg Cd on a yearly basis.

Biodiversity

In this study, the number of dragonfly species (Odonata) in the individual wetlands has been used as an indicator of the general biodiversity. The number of dragonfly species is highly correlated to overall biodiversity, but not, of course, to the biodiversity of every organism group. It can therefore only be used to get an overall view of the biodiversity of each wetland. The total number of species found in the wetlands in this study is relatively high, in fact the figures are comparable to those obtained during previous studies in more mature aquatic ecosystems (lakes) in forests, which indicates that constructed wetlands have a potential for high biodiversity. This is further supported by the occurrence of several particular species indicative of a high biodiversity, one of which is included on the EU habitat directive.

Constructed wetlands financed by Miva and Lmiva can be considered to have a greater potential for developing a high biodiversity than wetlands financed by LIP and PS. This is mainly due to that Miva wetlands generally are considerably larger, and that both Miva and Lmiva are less narrowly targeted support systems, whereas LIP and PS are primarily focused on nutrient retention. The number of dragonfly species was, indeed, found to be higher in wetlands financed with Miva and Lmiva. This could, however, also be attributed to the fact that these wetlands were, on average, older. The difference in species number between the support systems can therefore not with certainty be ascribed to actual differences in the location or design of the wetlands. Clear positive correlations were, however, found between the structure and abundance of vegetation, and the number of dragonfly species. When constructing wetlands, active management of the vegetation might therefore be an efficient way to increase the biodiversity. Apart from the vegetation, ecotones in the landscape seem to be of great importance to the community structure among the dragonflies. In the study, no clear evidence was found that the goal of nutrient retention stands opposed to that of biodiversity. It seems perfectly possible to combine efficient nutrient retention with high biodiversity.

Environmental quality objectives

The national environmental objectives pertaining to this evaluation are: “Zero eutrophication” and Thriving wetlands”. At lest two of the national interim targets are identified as directly related to this study. “By 2010 waterborne anthropogenic emissions in Sweden of phosphorus compounds into lakes, streams and coastal waters will have diminished continuously from 1995 levels”. “By 2010 waterborne anthropogenic nitrogen emissions in Sweden into the sea south of Åland Sea will have been reduced by 30% compared with 1995 levels, i.e. to 38,500 tonnes”

In our opinion, the results of this evaluation show that constructed wetlands in the agricultural landscape are capable of a substantial reduction in the nutrient (e.g., nitrogen) deposition in downstream recipients. Constructed wetlands also have a great potential to create habitats with a high biodiversity in areas deprived of most their formerly numerous wetlands. The study shows that constructed wetlands, in the right location, can reduce the transportation of nitrogen by more than 500 kg per ha and year (calculations based on actual water surface area). This exceeds the goal stated by the Swedish Board of Agriculture of 200 kg N per ha and year by 250%.

However, the wetlands constructed by means of various support systems between 1996 and 2002 have, on average, a nutrient retention of less than 100 kg N per ha and year, i.e. a total reduction in nitrogen deposition by no more than approximately 300 tons per year (3 300 ha wetland area). It is therefore important to revise the extant guidelines, particularly those applied to wetlands financed by the RDS system. Such new guidelines are in the process of being constructed by the Swedish Board of Agriculture

The 6000 hectares of wetlands due to be created by means of RDS until 2006 are expected to reduce the nitrogen transportation by 1200 tons per year. With the current guidelines, according to this study, the effect may only be 600 tons. However, the study indicates that the total nitrogen reduction potential of these wetlands could be 3 000 tons, provided that the guidelines and the construction principles are improved, and that the areas thus created are actual clear water surfaces. This might become a major contribution to the overall goal of reducing the nitrogen transportation by 20 000 tons on a yearly basis. The 12 000 hectares of constructed wetlands that are planned for the environmental objective “thriving wetlands” will also contribute to a reduced nitrogen transportation in the range of 50 – 100 kg N per ha and year, corresponding to a total of 600 – 1200 tons.

The wetlands also reduce phosphorus transportation, but to a lesser extent; 0.2-12 kg P per ha wetland area and year. This is mainly due to that there is less leakage of phosphorus from arable land. In other studies wetlands have been shown to be very effective in phosphorus retention, particularly when the source is highly localised, or in cases where the water contains high concentrations of particulate phosphorus.

The environmental objective “Thriving wetlands” states that the ecological function of wetlands in the landscape should be retained, and that valuable wetlands should be preserved. When constructing wetlands in an agricultural landscape, the biodiversity of the area will almost automatically increase due to the introduction of a new habitat. The average number of (dragonfly) species in the newly constructed wetlands was low, between 1.6 and 3.8 depending on support system. Previous studies of lakes indicated an average species number of 6.5 or more. It is hard to say whether or not constructed wetlands are capable of obtaining such high numbers given longer time to develop. The study shows that several threatened species are able to colonise the wetlands, thereby increasing their populations. This is arguably the most important function of constructed wetlands. The large number of wetlands due to be constructed will certainly increase the possibilities of dispersal and survival for a large number of species. An important prerequisite for this, however, is that the wetlands be diverse in design, with differences in depth, slopes, size etc, since different species have different habitat requirements.

Much work remains before we fully understand the role of wetlands as a means to achieve the environmental objectives. It is clear that monitoring and evaluation of the results achieved using various support systems has not been prioritised, and therefore severely neglected. In our opinion, increased resources for evaluation is an absolute prerequisite for exploiting the full potential of wetlands, both as nutrient traps and sources of increased biodiversity.