Biodiversity and ecosystem functioning in created agricultural wetlands

Geraldine Thiere[a] & Stefan E.B. Weisner[a]

[a] Wetland Research Centre, Halmstad University, Halmstad, SWEDEN (geraldine.thiere@hh.se - stefan.weisner@hh.se)

INTRODUCTION

Wetland creation at large, regional scales is implemented as a measure to abate biodiversity loss in agricultural landscapes and the eutrophication of waterscapes and coastal seas by non-point source nutrient pollution. The environmental consequences of creating many new wetlands for biodiversity conservation and nutrient retention are still largely unknown since we do not know to what degree the created wetlands will provide the expected ecosystem services on local (wetland) and regional (landscape) scales. Further, potential risks (climate gas emission) or potential interactions between ecosystem functions and with biodiversity need to be assessed in created wetlands. In Sweden, wetland creation has progressed since the 1990's and by now large numbers of created, pond-like wetlands have been established, mainly in the intensively farmed south-western region.

This research aimed to investigate the following aspects in these systems: (i) the large-scale effects of wetland creation on aquatic biodiversity, (ii) the functional diversity of bacterial denitrifiers in created wetlands, (iii) the influence of abiotic and biotic parameters on wetland ecosystem functioning, (iv) the potential for biodiversity-function links, and (v) the potential for function-function links and joint functioning (multiple purposes) in created agricultural wetlands.

METHODS

(i) The community composition and richness of aquatic macroinvertebrates and plants was investigated in 36 full-scale created wetlands. The effect of wetland creation on local and regional biodiversity was assessed by comparing three landscapes with varying wetland creation efforts (i.e. differing total wetland density), and by comparisons to the macroinvertebrate species pool of natural ponds in the same region.

(ii) Along with environmental parameters, biofilm communities of denitrifying bacteria were investigated in 32 full-scale created wetlands, employing a molecular community fingerprinting technique (PCR-DGGE). Three types of bacterial denitrifier communities (nirK, nirS, and nosZ) were characterized; their genomes encode the enzymes that catalyse two steps in the denitrification chain (key process for nitrogen removal). The composition and diversity of the enzyme gene communities present in created wetlands were set in relation to environmental parameters.

(iii) The capacity for nitrogen retention (beneficial ecosystem service) was estimated based on nitrogen load and temperature (Kadlec & Knight 1996), the capacity for diffusional methane emission (environmental risk) was estimated based on dissolved methane concentration (at equal temperature) in 36 created wetlands. Annual budgets were calculated to assess the total nitrogen retention and methane emission for the planned 12,000 ha wetland area in Sweden, and to test if environmental benefit and risk of wetland creation were linked. It was also tested which environmental parameters predicted diffusional methane production.

(iv) The effect of the biotic wetland setup on nitrogen retention and biodiversity (plants and macroinvertebrates) was tested in equally loaded experimental wetlands with different vegetation type (planted emergent; planted submerged; freely-developed). Further, nitrogen retention and biodiversity were studied during 4 subsequent years to test if differences between vegetation treatments were consistent over time.

(v) Three ecosystem functions (nitrogen retention, phosphorus retention, and litter decomposition) and the biotic setup (plant and macroinvertebrate diversity; vegetation extent) were measured in 14 full-scale created wetlands in 2 subsequent years. Each ecosystem function was set in relation to environmental parameters to assess if biotic factors, particularly diversity, influence ecosystem functions in highly dynamic wetlands. Further, the three ecosystem functions were evaluated jointly to see if wetlands may sustain simultaneous functions (multiple purposes) and if certain ecosystem functions are coupled.

RESULTS AND DISCUSSION

Biodiversity (Thiere et al. 2009). The requirements for nutrient retention (particularly high nitrogen loads) were not an obstacle for biodiversity development in created agricultural wetlands. Created wetlands served as equally valuable habitats than natural ponds. In landscapes with greater wetland creation efforts (increasing total wetland density by 30%), local plant and macroinvertebrate richness (per wetland) and regional macroinvertebrate richness (per landscape) were higher than in landscapes with low to moderate wetland densities.

Functional diversity (Thiere 2009). All investigated wetlands hosted diverse denitrifying bacterial communities, indicating that the capacity for early and late steps in the denitrification chain was established among created wetlands. The variation in diversity across enzyme gene types was linked to wetland environmental parameters, namely nitrate concentration and hydraulic loading rate, i.e. factors that were earlier shown to affect denitrification rate and/or the wetland capacity for nitrogen retention (Kadlec & Knight 1996). The enzyme gene communities encoding early (nirK and nirS) and late (nosZ) denitrification steps were equally diverse at high nitrate concentrations, but skewed towards the nir type at low nitrate concentrations.

Abiotic and biotic influences (Thiere 2009). After accounting for abiotic variation statistically, biotic parameters were shown to be linked to ecosystem functioning of highly dynamic created wetlands. For phosphorus retention, biotic factors explained most of the among-wetland variation; for nitrogen retention and litter decomposition abiotic factors were more important. Biotic influences on ecosystem functions were mainly mediated by the amount (biomass, cover) and dominant type of vegetation (emergent, submerged, macroalgae). High aquatic plant cover/biomass supported nitrogen retention and low methane production, but inhibited phosphorus retention and litter decomposition.

Biodiversity–function links (Thiere 2009). *Dynamic created wetlands*: Biodiversity parameters were positively related to process rates involved in nitrogen retention (functional diversity of plants and bacterial denitrifiers), phosphorus retention (plant richness) and litter decomposition (macroinvertebrate diversity). *Experimental wetlands with stable loads*: Nitrogen retention depended on vegetation state; wetlands with planted emergent vegetation had a higher nitrogen retention capacity than wetlands with planted submerged or freely-developed (algae-dominated) vegetation states. High nitrogen retention was sustained despite plant diversity loss over time in the emergent plant treatments.

Function–function links and joint functioning (Thiere 2009**).** Process rates involved in nitrogen retention were higher if litter decomposition was fast, indicating that certain ecosystem functions are coupled. Joint ecosystem functioning, i.e. the simultaneous performance of multiple functions and diversity was shown to be possible in at least some created wetlands.

CONCLUSIONS

Wetland creation contributes to abating the lost biodiversity and multifunctionality caused by past wetland destruction in agricultural landscapes. Created wetlands facilitate biodiversity, particularly on regional scale. Wetland ecosystem functioning is influenced by the 'biotic setup': diversity seems to support several wetland functions. Besides to choice of wetland location, the management of vegetation extent could direct wetland functioning and diversity in desired directions. As some functions are coupled, created wetlands may require management for multifunctionality, in order to sustain a specific ecosystem service.

REFERENCES

Kadlec, R.H. and Knight, R.L. (1996) *Treatment Wetlands.* CRC Press Boca Raton, Florida. 893p.

Thiere, G. (2009) Biodiversity and ecosystem functioning in created agricultural wetlands. PhD thesis, Limnology, Lund University.

Thiere, G., Milenkovski, S., Lindgren, P.-E., Sahlén, G., Berglund, O. and Weisner, S.E.B. (2009) Wetland creation in agricultural landscapes – Biodiversity benefits on local and regional scales. *Biol. Cons.* 142:964-973.