Nutrient dynamics in a semi-natural treatment reedbed

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

The Wildfowl & Wetlands Trust

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Introduction

Constructed wetlands and/or reedbed systems are increasingly being used to treat polluted water. Internationally the use of this type of eco-technology is regarded as an efficient nutrient removal method and is generally considered cheaper to operate than the industrial alternatives. Constructed wetlands also have the additional benefit of providing valuable habitat, which has the potential to support a wide range of wetland species. The efficiency of nutrient removal (and to some extent the ecological value of the habitat) depends on vegetation type, residence time, temperature (latitude), season, and age of the system. Whilst the nutrient removal rates of these systems are often monitored for the initial period following creation, there is a lack of long term monitoring and as a result there is a poor understanding of how removal efficiency changes with time. This work focuses on the nutrient dynamics in a multistage constructed wetland and compares data from the period directly after construction (1995 – 1996) with data collected over the past two years (2006 - 2007).

Objectives

The aim of this study is to evaluate the removal efficiency for a range of nutrient species, and to compare the percentage reduction rates of 11 years ago with those from the present day. This will help to answer the question, "how does the removal efficiency of this system change with time?"

Study Site

The study site is located at the 325 ha Wildfowl & Wetlands Trust Reserve (WWT) at Slimbridge in Gloucestershire. The reserve is a popular visitor attraction and boasts one of the world's largest collections of swans, geese and ducks. The wetland in this study (known locally as the South Finger reedbed) treats the wastewater that comes from the bird exhibit areas. Water enters the centre from the Gloucester & Sharpness canal and from adjacent agricultural land and passes through a series of interlinking exhibit ponds, which provide habitat for captive and wild birds, before flowing into a ditch which discharges into the River Severn. To improve quality of water leaving the exhibit ponds and reduce the pollution risk to the River Severn, the South Finger Wetland Treatment System (WTS) was installed in 1995.

The WTS which is primarily a horizontal surface flow system, comprises a settlement lagoon (Pond-1) followed by three parallel wetlands, two of which are monospecific stands of *Iris. pseudacorus* (Yellow Flag) (Iris bed) and *Phragmites australis* (Common Reed) (Phragmites bed), the third comprises a mosaic (mosaic bed) of wetland plant species including *Typha latifolia* (Greater reedmace)*, Carex riparia* (Pond Sedge) and *Sparganium erectum* (Branched Bur-reed). All of them discharge into a rafted lagoon, which contains artificial rafts planted with *Rumex hydrolapathum* (Water Dock) and the water then passes over a chalk cascade and through the cascade lagoon (Pond-2) before passing into either a *Schoenoplectus lacustris* (Common Club-rush) (Scirpus bed) or *Phragmites australis* (Phragmites–2 bed) and finally into the discharge ditch draining into the River Severn (Figure 1), (Price, and Probert, 1997).

Methods

CEH has conducted chemical water quality monitoring at Slimbridge since October 2005. Water samples are taken on a monthly basis and are analysed for the following parameters: nitrate (NO3-N), ammonium (NH4-N), orthophosphate (PO4-P), soluble reactive phosphorus (SRP), and total phosphorus (TP). Particulate phosphorus (PP) is calculated as TP-SRP. These data were collected between December 2006 and October 2007 and were compared with those collected by Millet (1997) between February 1995 and March 1996, during the first two years of the system's operation. The percentage removal of each parameter was calculated as follows:

$$\% \ Removal = \frac{Cin - Cout}{Cin} x100$$

where: Cin = concentration of nutrient in inflow system or subsystem (mg/l), and Cout = concentration of nutrient in outflow system or subsystem (mg/l). Positive values indicate a decrease in concentration (removal) and negative values indicate an increase (addition).

Results

The mean and standard deviation of nutrient concentrations for the period from December 2006 to October 2007 for each location, including a sample taken before the water enters the exhibit ponds (Reserve), are shown in Table 1. The phosphorus concentration increases between the Reserve sample and the ditch (inflow to the WTS) because the exhibit ponds in the centre provide habitat for up to 2000 wildfowl in summer months and up to 3000 wildfowl during winter months. This results in a significant loading of nutrients to the system.

Nitrogen. During 2006/2007, ammonia is reduced by nearly 60% and nitrate by 36.7 % compared to ten years ago when the reduction was nearly 20 % for both (figure 2). However the removal mechanism has changed; in 1995/1996 the reduction in nitrate and ammonia was low but positive whereas ten years later the reduction of nitrate has became negative and the reduction of ammonia has increased in pond-1, as a consequence of the ammonification and denitrification processes which are occurring because the open water areas are now predominantly anaerobic (measured level of oxygen < 2 mg/l) (figure 3). However in the three parallel beds the predominant process is nitrification because the vegetation maintains aerobic conditions in the sediments.

Phosphorus. The reduction in 1995/1996 of TP was 20 %, SRP; 5.2 % and PP 100%. Ten years later the reduction of TP and PP have decreased by nearly half and the SRP reduction is now negative (-40%) (figure 2). Whereas originally the system was efficient at removing P the 2006/2007 data indicate that the efficiency is now reduced which is in part due to the release of SRP from the decaying vegetation which is accumulated year by year in the bottom of the wetland and the adsorption mechanisms of the sediments are now saturated with respect to phosphorus.

Conclusion

In the 10 years between monitoring, the wetland system has become more efficient at the removal of nitrogen, but less efficient at removing phosphorus. If the objective is to maintain efficient removal of phosphorus then some form of management is required. A future study which will assess various management practices, including sediment removal, increased hydrological retention time and vegetation harvesting at the end of the growing season, will consider which of these is the most cost effective.

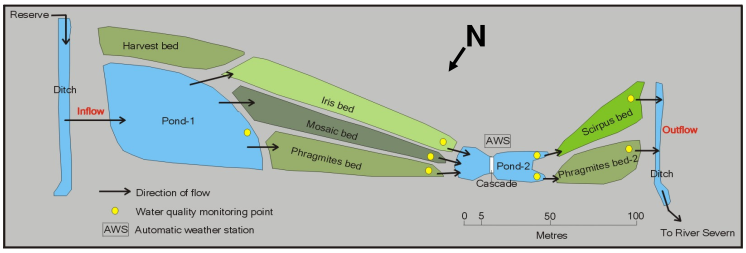

Figure 1. Layout of the Slimbridge South Finger Wetland Treatment System.

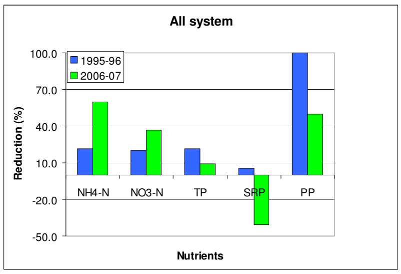

Figure 2. Reduction (%) of nutrients in the whole system, determined between inflow and outflow.

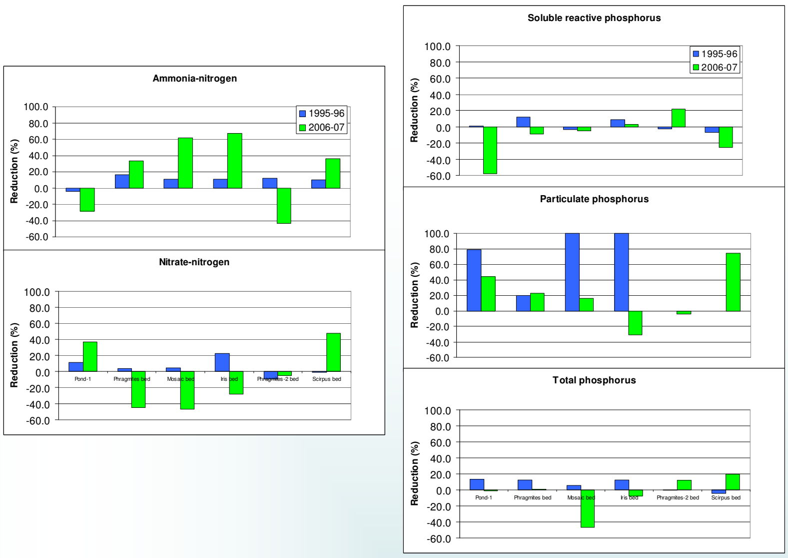

Figure 3. Reduction (%) of nutrients in every part of the system in 1995/1996 and in 2006/2007 determined between the inflow and outflow of each subsystem.

Table 1. Mean and standard deviation (sd) in mg/l of the principal nutrient concentrations measured during last year in different parts of systems including the nutrient concentrations before entry into the Slimbridge Reserve.

All in mg/l	NH_4-N		NO_3-N		TP		SRP		PP	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Reserve	0.08	0.10	15.8	5.7	0.16	0.01	0.12	0.03	0.04	0.02
Ditch (inflow)	1.64	0.44	9.9	6.9	0.78	0.42	0.35	0.34	0.43	0.16
Pond-1	2.10	1.73	6.3	5.1	0.79	0.72	0.55	0.68	0.24	0.11
Phragmites bed	1.40	1.49	9.1	4.7	0.78	0.64	0.60	0.53	0.18	0.11
Mosaic bed	0.80	0.89	9.2	5.0	1.16	1.43	0.58	0.39	0.20	0.13
Iris bed	0.69	0.59	8.0	5.7	0.85	0.71	0.54	0.37	0.31	0.36
Phragmites-2 bed	0.80	0.47	8.7	2.5	0.75	0.35	0.41	0.12	0.34	0.29
Scirpus bed	0.51	0.68	3.8	3.1	0.67	0.39	0.57	0.36	0.10	0.04

Acknowledgements

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