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The Effects of Beaver-created Wetlands on Surface Water Quality of Lotic Habitats in Northern Illinois

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ABSTRACT

We examined 41 chemical parameters in water samples taken upstream and downstream from 7 beaver-created wetlands in DuPage County, IL. Overall, a significant majority of parameters (18 of 26) present in detectable amounts had lower concentrations in downstream samples, suggesting that these wetlands do serve to improve water quality by filtering out some pollutants. However, only 5 of these parameters had statistically significant differences between upstream and downstream samples (manganese, arsenic, sulfate, total solids, and calcium) and 2 of these actually had higher concentrations downstream (manganese and arsenic). This suggests that materials used by beavers in dam construction (e.g., cornstalks, treated lumber) may also serve to reduce certain aspects of water quality.

INTRODUCTION

Wetlands may act as natural filters, removing dissolved and solid pollutants from aquatic ecosystems (e..g., Whigham et al. 1988, Agovina 1990, Verhoeven et al. 2006). For example, artificial wetlands (especially those associated with wastewater treatment) remove significant quantities of various compounds including nitrogen, phosphorus, total suspended solids, and sulfates (Gersberg et al. 1984, 1986, Bowmer 1987, Breen 1990, Shutes 2001, Jiang et al. 2007, Pankratz et al. 2007). Data from natural wetlands also indicate positive effects on downstream water quality, although these effects are often complex (Richardson 1985, Whigham et al. 1988, Montreuil and Merot 2006, Verhoeven et al. 2006).

Beaver-created wetlands are one type of natural wetland that could also improve water quality in downstream areas. For example, Parker et al. (1985) found reduced concentrations of nitrogen, suspended solids, and phosphorus downstream from beaver wetlands. Other studies have also indicated that beaver ponds may reduce downstream transport of sediments, nutrients, and pollutants (e.g., Naiman and Melillo 1984, Francis et al. 1985, Maret et al. 1987, Cirmo and Driscoll 1993).

In this study, 41 chemical parameters were examined from water taken above and below beaver-created wetlands in DuPage County, Illinois. This study was designed to examine the effects that these urban populations of beavers had on water quality of the associated streams and rivers.

MATERIALS AND METHODS

Study Area

This study was conducted on lands owned by the Forest Preserve District of DuPage County in northeastern Illinois. This preserve system encompasses more than 10,100 hectares in 60 preserves. Numerous marshes, rivers, and streams within this preserve system support beaver populations.

Site Selection

Beaver wetlands used in this study were selected based on the following criteria. The site had to (1) have an active beaver colony that was maintaining a dam, (2) be located on land owned or managed by the Forest Preserve District of DuPage County, (3) be associated with a lotic ecosystem with clearly delineated single points of inflow and outflow, and (4) have no close association with other wetlands. Seven beaver-created wetlands were found that met these criteria.

Water Sample Collection

We collected surface water samples in 500 ml high-density polyethylene, wide-mouthed bottles that had been washed with 1 N HCL to remove possible contamination. One sample was taken upstream and one downstream from each beaver wetland. “Upstream” samples were collected approximately 25 m upstream from the impact area of the wetland where significant surface water movement was still occurring. “Downstream” samples were collected at least 5 m but no more than 20 m downstream from the beaver dam. We took all samples from the middle-third of the stream or river.

Analysis of Chemical Parameters (Techniques used for the first two sampling dates, 27 June and 10 July 1991)

The concentration of dissolved calcium (Ca^{++}) was determined using the EPA-approved EDTA titrimetric method with Eriochrome Black T as the indicator (APHA 1985). Concentrations of dissolved chloride (Cl^{-}) were determined using reagents obtained from Hach Company (Lovelend, CO) utilizing the EPA-approved silver nitrate buret titration method using 0.0141 N $AgNO_3$ (Hach Company 1989). Dissolved nitrate (NO_3^{-}) concentrations were determined using a hybrid method that utilized Hach’s NitraVer 5 nitrate reagent powder pillow. This reagent contains the necessary chemicals to apply the cadmium reduction method for photometric determination of nitrate. The NitraVer 5 was added to 25 ml of the water sample in test tubes that had a path length of 2.5 cm after which samples were analyzed spectrophotometrically (Spec 21) to determine optical density at a wavelength of 400 nm. Samples of known nitrate concentration were used to construct a concentration vs. transmittance curve. Applying this curve, the concentrations of the samples could be determined. Dissolved sulfate (SO_4^{-2}) concentrations were determined with a hybrid method using Hach’s SulfaVer 4 powder pillow and test tubes with a 2.5cm path length. Optical density at 450 nm was determined using a spectrophotometer (Spec 21) and a standard curve was constructed utilizing a stock sulfate solution (APHA 1985).

Methods used for the Entire Study. Total phosphorus (tP) concentrations were determined using Standard Methods’ Ascorbic Acid Method and persulfate digestion. The pH was determined using a dO_2 meter and a Yellow Springs Instrument Company probe. Total solids (TS) were determined by using a 50 ml porcelain drying dish into which 40 ml of the water sample were added. We dried the sample in an oven overnight at 98°C, then for an additional 15 min at 110°C and then cooled the sample in a desiccator for one hr. The samples were then weighed to the nearest 0.0001 g. Total non-volatile solids were determined by ashing the TS sample in a 510°C muffle furnace for 15 min and then weighing it after it had cooled. Total volatile solids (TVS) were determined by taking the mathematical difference between TS and TNVS.

Methods used for the last 6 sampling dates. Concentrations of dissolved arsenic (As) and dissolved cadmium (Cd) were determined using inductively coupled plasma/mass spectrometry (ICP/MS; method 6010-EPA-5w846). Other dissolved metal concentrations were determined by inductively coupled plasma-optical emission spectroscopy (ICP-OES; method 6020-EPA-5w846). Beginning with the sample collected 16 July 1991 (the third sample), dissolved sulfate, dissolved chloride, dissolved nitrate, dissolved fluoride, and dissolved bromide concentrations were determined using ion chromatography (IC; method 300-Mcaww-EPA).

The EPA-approved ICP/MS, ICP-OES, and IC methods were performed by Dave Roberts of the Enesco Rocky Mountains Analytical Laboratory in Arvada, CO. Samples were sent by overnight express mail in a 0°C cooler and preserved with nitric acid upon receipt by the lab. Table 1 summarized the parameters we examined, the method utilized for analysis, and the detection limits for each.

Table 1. Water quality parameters examined from water samples collected at beaver-created wetlands in DuPage County, IL. Detection limits in ppm except pH.

Parameter (symbol)	Detection limit	Detection Method
Aluminum (Al)	0.009	ICP-OES
Silver (Ag)	0.002	ICP-OES
Arsenic (As)	0.001	ICP/MS
Barium (Ba)	0.003	ICP-OES
Beryllium (Be)	0.002	ICP-OES
Boron (B)	0.005	ICP-OES
Bromide (Br-)	0.2	IC
Cadmium (Cd)	0.001	ICP/MS
Calcium (Ca)	0.1/0.01	Titrimetric/ICP-OES
Chloride (Cl-)	5/3	$AgNO_3$ Titrimetric/OC
Chromium (Cr)	0.006	ICP-OES
Cobalt (Co)	0.004	ICP-OES
Copper (Cu)	0.004	ICP-OES
Iron (Fe)	0.007	ICP-OES
Fluoride (F-)	0.1	IC
Lead (Pb)	0.01	ICP-OES
Lithium (Li)	0.002	ICP-OES
Magnesium (Mg)	0.008	ICP-OES
Manganese (Mn)	0.003	ICP-OES
Molybdenum (Mo)	0.005	ICP-OES

Parameter (symbol)	Detection limit	Detection Method
Nickel (Ni)	0.004	ICP-OES
Nitrate (NO_3^-)	0.1	NitraVer 5/IC
Dissolved Phosphorus (dP)	0.09	ICP-OES
Total Phosphorum (tP)	0.1	Ascorbic Acid
Potassium (K)	0.2	ICP-OES
Antimony (Sb)	0.02	ICP-OES
Selenium (Se)	0.05	ICP-OES
Silica Oxide (SiO_2)	0.2	ICP-OES
Strontium (Sr)	0.02	ICP-OES
Tin (Sn)	0.03	ICP-OES
Sodium (Na)	0.1	ICP-OES
Sulfate (SO_4^{2-})	5	IC
Thallium (Tl)	0.5	ICP-OES
Titanium (Ti)	0.003	ICP-OES
Vanadium (V)	0.004	ICP-OES
Zinc (Zn)	0.002	ICP-OES
Total Solids (TS)	25	Standard Methods
Total Volatile Solids (TVS)	25	Standard Methods
Total Non-volatile Solids (TNVS)	25	TS-TVS
pH	0.1 units	Field pH meter
Dissolved Oxygen (dO_2)	0.1	YSI meter and probe

Data Analysis

We sampled all 7 wetlands for the first two sampling dates (27 June and 10 July 1991), after which the dam associated with one wetland was destroyed. Water levels became low enough to preclude sampling in 3 other wetlands after the second sampling date as a result of a drought. Because of this situation and the fact that certain methods varied between the first two and last 6 sampling dates, we analyzed our data as 2 separate balanced data sets. The first data set ("data set 1") consisted of 7 wetlands sampled over two dates. The second data set ("data set 2") consisted of 3 wetlands sampled over the last 6 sampling dates (for most parameters) and all 8 sampling dates for calcium, chloride, nitrate, sulfate, pH, dissolved oxygen, and total solids. We used repeated-measures ANOVA to analyze both data sets, with sampling date as the repeated measure. Chemical parameters were analyzed separately. However, the following chemical parameters were typically below detection limits and so were excluded from the statistical analyses: silver (Ag), beryllium (Be), chromium (Cr), cobalt (Co), lithium (Li), lead (Pb), antimony (Sb), selenium (Se), tin (Sn), thallium (Tl), titanium (Ti), and vanadium (V).

RESULTS

Data set 1 (7 wetlands, 2 dates)

We failed to find any significant differences between upstream and downstream concentrations for this data set (ANOVA, all $F < 3.75$, $P > 0.05$), although sulfate concentrations were marginally lower downstream ($F = 3.74$, $P = 0.10$).

Data set 2 (3 wetlands, 6 dates)

Five parameters showed significant differences between upstream and downstream concentrations (ANOVA, $P < 0.05$, Table 2). Three parameters (SO_4^{-2}, TS, and Ca) had lower average concentrations downstream and two (Mn and As) had higher average concentrations downstream. Overall, 18 parameters had lower average concentrations downstream, 8 had higher concentrations downstream and one (pH) was the same (chi-square = 3.85, df = 1, $P < 0.05$).

Table 2. Comparison of upstream and downstream concentrations of water quality parameters for 3 beaver-created wetlands over 6 sampling dates. All concentrations are in ppm (except pH); see Table 1 for key to parameter abbreviations.

Parameter	Mean Upstream Concentration	Mean Downstream Concentration	Percent Difference	Sig. of F-Statistic
Mn	0.0205	0.3281	+1500*	0.02**
As	0.022	0.050	+127	0.02**
SO_4^{2-}	114.7	85.5	-25	0.04**
TS	1590	1254	-21	0.05**
Ca	114.4	98.6	-14	0.09**
Fe	0.0292	0.0920	+215	0.16
Al	0.0267	0.0519	+94	0.22
Cl-	258	317	+23	0.024
Na	259.8	197.4	-24	0.27
Mg	55.08	47.88	-13	0.32
Mo	0.0125	0.0105	-16	0.40
Zn	0.0121	0.0092	-24	0.40
tP	0.5194	0.6694	+29	0.41
F-	1.3429	1.1095	-17	0.41
Sr	0.5205	0.4248	-18	0.53
B	0.3240	0.2902	-10	0.58
Ba	0.1920	0.1629	-16	0.59
NO_3^-	1.0343	1.2014	+16	0.65
K	6.7571	6.2095	-8	0.67
Cu	0.009	0.008	-11	0.67
Br-	0.2571	0.2381	-7	0.73
Ni	0.0041	0.0039	-5	0.73
dO_2	5.2	5.1	-2	0.73
dP	0.6743	0.6114	-2	0.76
pH	7.4	7.4	0	0.83
Cd	0.018	0.016	-11	0.84
SiO_2	4.9429	4.9571	+0	0.99

*'+' denotes higher concentration downstream; '-' denotes lower concentration downstream

**$P < 0.10$, ANOVA

DISCUSSION

Wetlands are thought to act as biological filters, removing dissolved and solid pollutants and improving water quality (Feeney and Morrell 1985, Hair 1986, Agovina 1990, Verhoeven et al. 2006). Thus, our prediction was that beaver wetlands would improve water quality by lowering concentrations of pollutants in our downstream samples. However, most parameters did not differ significantly upstream and downstream from beaver wetlands. Of those parameters that did differ 2 of the 5 (Mn and As) actually had higher concentrations downstream. Arsenic used to be a common preservative added to treated lumber, so if beavers imported treated lumber in the construction of their dams, leaching from this material may explain our results. Given the proximity of our beaver wetlands to human development, this is certainly possible. However, we did not notice any type of finished lumber in the beaver dams in this study, and neither chromium nor copper were similarly elevated downstream (other elements used in treated lumber; Lebow et al. 1999), so the explanation of this result remains problematic. However, arsenic was used in pesticides prior to 1993, and can be taken up by corn in measurable concentrations (Parsons et al. 2008). In addition, manganese is found in corn, and beavers are known to commonly eat corn in the Midwest. Furthermore, we have seen cornstalks used in beaver dam construction.

Although our small sample of wetlands probably contributed to our lack of significant results, we did find that a significant majority of parameters had lower concentrations downstream. This suggests that our beaver-created wetlands do serve to filter out some pollutants. However, items brought into the aquatic system by beavers (e.g., corn, treated lumber?) may also serve to reduce water quality downstream from these wetlands.

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