Sediment Assessment in a Wetland Restoration Project

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Abstract

The study site has historically been used for industrial operations, but is now the location of the Roanoke/Cashie River Center, a science museum. Wetland restoration was initiated as part of the science center development. Concern that previous industrial uses would impact the development of the wetlands prompted evaluations. Sediments were examined for the presence of macroinvertebrates, analyzed for physical characteristics, and evaluated in toxicity tests. Duplicate samples were collected from the large and small wetlands. Initial examination of sediment indicated few indigenous organisms. Macroinvertebrate recruitment into the wetlands was evaluated using benthic colonization samplers. After four weeks, samplers were retrieved and analyzed. There were significantly more organisms (number of species and number of individuals) found in recruitment samplers than in indigenous populations. Sediments were also tested in ten-day toxicity tests with the amphipod *Hyalella azteca*. Survival was reduced in sediments from both wetlands for samples collected in November and February. It does appear that there is contamination associated with sediments that is inhibiting the development of sediment organism populations.

Introduction

Two wetlands were recently constructed at a new environmental education center. The Roanoke/Cashie River Center, located in Windsor, North Carolina, was established by the Partnership for the Sound to promote ecotourism and educate the community about (local) wetlands. From 1941 until the present, the study site was used for a variety of industrial purposes, such as a railway company, a veneer company, and a lumber company. There is also anecdotal information that the site may have been used as a World War II camp for soldiers. Because of concern that historical contamination might inhibit the development of the wetlands or might pose a risk to visitors to the science center, an evaluation of the wetlands was initiated.

Persistent contaminants and materials from previous industrial uses would most likely accumulate in sediments, which could directly affect sediment organisms. Sediment organisms are a key component to the development of a functioning wetland. Therefore, the focus of this research is wetland sediments. Three questions were addressed to determine the status of the sediment in these wetlands. First, what are the indigenous sediment organism population numbers? Then, if the indigenous population numbers are low, is it, second, because there are not enough organisms entering the wetland that could colonize the sediment, or third, because the sediments are toxic?

Materials and Methods

Characterization of Wetlands

There were two wetlands located on the site, referred to below as the “large” and “small” wetland. The wetlands were divided into sections. Sediments were randomly sampled from sections of each wetland and characterized for percentages of sand, silt, clay, and organic matter. Sediment was dried at 105°C in a drying oven, removed from the oven, and homogenized. Approximately 100g of the dried soil was weighed and sieved through a 2mm sieve. The portion of soil greater than 2mm was the coarse fraction. The remaining soil that passed through the sieve was used for the particle size analysis (Brewer and McCann, 1982). The percent of organic matter was measured by combustion of a preweighed amount of sediment in a muffle furnace at 550°C. Water samples were collected from each wetland and analyzed for pH, dissolved oxygen, temperature, conductivity, alkalinity, and hardness. The temperature and dissolved oxygen were measured using a YSI Model #57 dissolved oxygen meter. The pH was

measured using a Corning model 30 pH meter. The conductivity was measured using a YSI Model # 30 conductivity meter. The hardness and alkalinity were analyzed according to Standard Methods (APHA, 1989). Ten-day aqueous toxicity tests were also done on water column samples from each wetland using 24-hour-old Daphnia magna.

Indigenous Organisms Study

An assessment of indigenous sediment organism populations in the two wetlands was conducted. The wetlands were divided into sections. The small wetland (3,725 square feet and approximately five feet deep in the middle) was divided into four equal sections. The large wetland (43,750 square feet and an average depth of three feet) was divided into six sections. The wetlands contained various types of reeds, grasses, and cattails. Duplicate samples of the top 2 cm of sediment were collected with a shovel from each section and brought back to the lab. Three hundred ml of each sediment sample were sieved through a series of three sieves (1mm, 600µm, 250µm) and all organisms collected. The number and type of organisms in each sample were recorded. Statistical evaluation of the data was done using the Shannon-Wiener Diversity Index ($H' = - \_ (p_i)(\log_2 p_i)$. This index was used to evaluate diversity, defined as a measure of the number of species present and the number of individuals within each species, and to evaluate how evenly distributed those individuals are among the species.

Recruitment Study

To determine whether there were enough organisms entering the wetland that could colonize the sediments, a recruitment study was conducted. Recruitment, or the number of organisms entering the wetland in a given period of time, was evaluated using a set of six recruitment samplers. The samplers were constructed with eight pieces of 4" diameter PVC pipe evenly spaced and glued onto a piece of 17" x 24" PVC board. A 300mL plastic cup was placed inside each piece of pipe. Each container was filled with 300 ml of reference sediment. Reference sediment was collected from a nearby uncontaminated wetland with sediment characteristics similar to the test wetland.

Two recruitment samplers were placed into each wetland on opposite ends and anchored in place. Two samplers were placed into a nearby uncontaminated wetland (Lake Vann) for comparison. After four weeks the plates were retrieved, the sediment sieved through a series of three sieves (1mm, 600µm, 250µm), and the organisms collected. The number and type of organisms in each sample container was recorded. Statistical evaluation of the data was done using the Shannon-Wiener Diversity Index.

Toxicity Tests

A series of sediment toxicity tests were conducted to evaluate the contamination and toxicity of the wetland sediments. Sediment samples were collected from each section of each wetland in duplicate with a shovel. Samples were collected in July 1999, November 1999, and February 2000. The top two cm of sediment were collected and placed into Ziploc bags which were placed on ice and brought back to the lab. In the laboratory, toxicity tests were set up for each section sampled. Seventy grams of sediment was placed into three replicate 250mL beakers with 160mL of filtered pond water added on top. Three replicate control beakers of documented uncontaminated sediment were also set up. Ten amphipods, *Hyalella azteca* (a standard EPA sediment toxicity test organism) were added to each beaker, and ten maple leaf circles were added to each beaker for food. The beakers were then placed into an incubator set at 20°C $\pm$ 2°C with sixteen hours of light and eight hours of darkness per day. Each toxicity test had a ten-day duration. At the end of ten days, each beaker was sieved and the number of live animal recorded. Dunnett's test was used to calculate statistical significance of survival in test samples compared to control sediment. The results were compared at a level of $P = 0.05$.

Results

Characterization of Wetlands

Average water quality parameters for the two wetlands shown in Table 1 were all within reasonable limits of survival of organisms. Water column toxicity tests with *Daphnia magna* resulted in 100% survival of all organisms, indicating no contamination in the water column. Table 2 shows the results of the sediment characterization. The wetlands had average values of 52% sand, 26% silt, 22% clay, and 5.6% organic matter.

Indigenous Organisms Study

Table 3 shows the results of the sediment population evaluations. There were five different taxa in Section 1 of the small wetland and Section 1 of the large wetland but only two different taxa of organisms found in Section 3 of the small wetland. The sediment samples also had low numbers of individuals present for each of the groups represented. The total numbers of individuals collected was as low as eight in Section 4 of the small wetland and as high as 133 in Section 1 of the small wetland. Table 4 gives the results of the Shannon- Wiener Diversity Index for the indigenous population evaluations. The H' value is less than 1, indicating very low diversity. The J' or evenness is less than 0.5, indicating that the number of individuals is not evenly distributed among species.

Recruitment Study

Results of the recruitment study are given in Table 5. The maximum number of taxa colonizing the recruitment sampler was eleven found in plate one of the small wetland, and the minimum number of different taxa was seven, in plate one of the large wetland. A total of 501 individuals was found in plate one of the small wetland and a minimum of 268 individuals in plate two of the small wetland. The numbers of the recruitment study and the indigenous study were adjusted so that comparisons were done using equal volumes of sediment. The Shannon-Wiener Diversity evaluation of the recruitment study (Table 4) showed a higher H' value, or an increase in diversity compared to the indigenous populations. The evenness values were similar to the indigenous population, showing that again there were many more individuals of some species present than others. The level of diversity found in the samplers placed into a nearby uncontaminated control wetland were similar to the level of diversity for organisms coming into the wetland as measured in the recruitment study.

Toxicity Tests [Figures referred to below are not available online.]

Figure 1 shows the toxicity test results for amphipods tested in sediments collected from the small wetland. Each bar represents the average percent survival of amphipods. The red bar is for samples collected in July 1999, the blue bar for samples collected in November 1999, the yellow bar for February 2000 samples. Those samples marked with an asterisk had statistically reduced survival compared to control samples. Survival less than 80% is considered biologically significant. Only two samples out of twelve had survival above 80%. There was a lot of variability between the July and November samples for Section 1 and 2 for the small wetland; both July samples had survival of approximately 65% while the November samples were 85% to 90%. In Section 3 the survival of organisms in the July sample was approximately 60% and survival in the November sample was nearly 80%.

Figure 2 shows the toxicity test results for amphipods tested in sediments collected from the large wetland. Samples collected in July 1999 are represented in red, November 1999 in blue, and February 2000 samples in yellow. Seven samples out of 18 had greater than 80% survival, but one sample had only 50% survival and was the only sample with statistically significant mortality compared to the control. Some sections had a great deal of variability between sample dates. Control survival was greater than 80% in all tests.

Figure 3 shows the average of all toxicity test results. Sediment samples tested for the small and large wetlands were averaged for samples collected in July 1999, November 1999, and February 2000. The red bars represent the small wetland, blue bars represent the large wetland, and the green bars represent the control. The July samples show that both the large wetland samples and the control samples had an average survival above 80%. The range of survival for

the small wetland ranged from 58% to 78%. The large wetland survival rate only ranged from 75% to 87%. For samples collected in November and February, for both the small and the large wetland, the amphipod survival was less than 80%. The range of amphipod survival for the small wetland in the November samples was 60-90%. The large wetland was also 60-90%. The control sediment amphipod survival was well above 80%. February results were similar between the two wetlands. Both the small and the large wetland sediment sample average survival rate was approximately 65%. The small wetland survival ranged from 57% to 80% while the large wetland survival ranged from 50% to 77%.

Discussion

The water quality and aqueous toxicity tests results indicate that the water was not contaminated and that parameters were within suitable ranges for survival of organisms. When the sediment samples collected from each wetland were initially examined, the results showed low indigenous population numbers of organisms. There was also low diversity, or few groups of organisms and not many individuals in each group in this study. The Shannon-Wiener Diversity Index also gave low evenness numbers in the indigenous study, which means that there were more individuals of one taxa than another. Those few individuals and groups present had greater tolerance for the sediment conditions and likely contamination. In the recruitment study the results revealed higher numbers of taxa and individuals in each taxa which suggest a greater diversity. These results suggest that organisms are entering the wetlands but are not surviving. The aqueous toxicity tests showed no mortality; therefore, any contamination present is likely associated with the sediment.

Sediment toxicity tests were conducted to confirm the presence of toxicity in the sediments. Mortality rates varied between sections. Some sediment samples demonstrated a biologically significantly mortality rate while other sections showed a mortality rate above 80%. This suggests that the contamination is not evenly spread throughout the wetland. The averages of the small wetland showed that the small wetland survival rate decreased from July 1999 to November 1999 and then increased in February 2000. The average percent survival in the large wetland decreased slightly between July and November 1999 and decreased even more between November 1999 and February 2000. Three hurricanes occurred during November 1999, Hurricanes Dennis, Floyd, and Irene. Like much of the state, this study site was flooded with approximately six feet of water. The entire town of Windsor was flooded, so a variety of additional contaminants may have been brought in with floodwaters. Alternatively, the rapid flow of floodwaters may have stirred up deeper layers of wetland sediments that had higher concentrations of contaminants. Whatever the cause, the toxicity test results show that some type of contamination is contributing to mortality rates that are biologically significant. The combination of low indigenous populations of organisms and reduced survival in sediment toxicity tests indicates that there is contamination associated with sediment that is likely inhibiting the development of the newly constructed wetland.

Works Cited

APHA. *Standard Methods for Examination of Water and Wastewater*. 17th ed. Washington, D.C.: American Public Health Association, 1989.

Brewer, R., and M.T. McCann. *Laboratory and Field Manual of Ecology*. New York: Saunders College Publishing,1982.

Table 1. Example of water quality parameters for the large and small wetland measured on October 18, 1999. Temperature and dissolved oxygen vary with season

WATER QUALITY	Large Wetland	Small Wetland
Temperature (°C)	27.1	27.4
Dissolved Oxygen (mg/L)	9.8	11.8
Conductivity (uS)	207.1	214.7
Salinity (ppt)	0	0
Alkalinity (mg/L as $CaCO_3$)	14	11
Hardness (mg/L as $CaCO_3$)	36	52

Table 2. Results of the wetland sediment characterization.

	LARGE				SMALL		REFERENCE
	Section 1	Section 2	Section 3	Section 4	Section 1	Section 2	Clean Sediment
% Sand	42	65	58	38	42	69	62
% Silt	32	18	21	34	32	18	21
% Clay	26	17	21	28	26	13	17
% Organic Matter	2.8	3.4	1.8	20.4	4.3	0.9	5.3

Table 3. The groups and the number of individuals in each group for the indigenous populations in the small and large wetlands (numbers have been adjusted for volume comparison).

LARGE WETLAND

ORGANISM	Sect. 1	Sect. 2	Sect. 3	Sect. 4	Sect. 5	Sect. 6
Tubificidia	10		4	3	3	2
Lumbriculida	69	10	37	55	22	12
Nematoda	22	3	18	30	5	2
Chironomidae	2	1	2	1	3	3
Plecoptera	1					
Total # Groups	5	3	4	4	4	4
Total # Individuals	104	14	61	89	33	19

SMALL WETLAND

ORGANISM	Sect. 1	Sect. 2	Sect. 3	Sect. 4
Tubificidia	11	2		
Lumbriculida	97	40	28	6
Nematoda	23	14	6	

Chironomidae	1	1		1
Plecoptera	1			1
Total # Groups	5	4	2	3
Total # Individuals	133	57	34	8

Table 4. Results of the Shannon-Wiener Diversity Index for indigenous sediment populations test and the recruitment study are shown. H' represents species diversity and the J' represents the evenness.

		Indigenous	Recruitment
Large Wetland	H'	0.96	1.69
	J'	0.41	0.51
Small Wetland	H'	0.79	1.13
	J'	0.34	0.33
Control	H'	N/A	1.29
	J'	N/A	0.36

Table 5. The groups and the number of individuals in each group for the recruitment study in the small and large wetland are shown. Numbers have been adjusted for volume comparison.

Organism	LARGE WETLAND		SMALL WETLAND		CONTROL
	PLATE 1	PLATE 2	PLATE 1	PLATE 2	PLATE
Tubificida	120	124	332	126	152
Lumbriculida	277	136	117	110	95
Nematoda	10	9	13	12	9
Chironomidae	9	10	8	6	5
Plecoptera			2	1	6
Cladocera		1	1	1	5
Amphipoda		2	2		5
Coleoptera					1
Copepoda	8	1	3	1	3
Hirudinea					2
Ephemeroptera		12	13	4	8
Gastropoda					3
Odonata	2	1	2	1	
Unionoidae					1
Trichoptera	1	8	8	6	
Total # Groups	7	10	11	10	12
Total # Individuals	427	304	501	268	290