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A Study of the Impact of Walker Lake on the North Branch of Middle Creek Using Metrics Generated by Diatom Biofilm Communities

Shannon Ryan
Susquehanna University

Jack R. Holt
Susquehanna University

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Shannon Ryan and Jack R. Holt

Ecology Program, Susquehanna University, Selinsgrove, PA 17870

Abstract

Middle Creek is a tributary of the main stem of the Susquehanna River, and its watershed is confined mostly to Snyder County. The upper reaches of the stream are defined by two major branches, the North Branch and the West Branch, each of which is interrupted by a reservoir, Walker Lake and Faylor Lake, respectively. Walker Lake is an impoundment of a deep V-shaped valley and is 9-10 meters deep at the dam, which allows it to be stratified in the summer and winter. Summer stratification produces an anoxic hypolimnion, which is drawn off by the bottom outflow dam into the North Branch. During September of 2019 and 2020, the hypolimnion of Walker Lake became anoxic and its outflow below the dam had a strong odor of hydrogen sulfide with deposits of iron (III) oxide-hydroxide covering the cobbles and small boulders. The purpose of this preliminary investigation is to explore the impact of the bottom outflow below the dam and at sample sites downstream before and after fall turnover on the diatom biofilm communities and use them as proxies for the state of the stream. We examined five sites on the North Branch: above the lake (1.5 km above the lake), Walker Lake, below the dam at its outflow, a site 1.2 km downstream called Old Bridge, and a site 3 km from below the dam called Swift Run Confluence. Field measurements, using a YSI 556 multimeter, of pH, conductivity, and % oxygen saturation showed clear impacts when the lake was stratified but began to moderate following fall turnover. The loss of alkalinity and conductivity were particularly noticeable. The alkalinity decreased by 35% between the above site (2,350 µeq/L) and below the dam (1,514.4 µeq). Before turnover, at the below site, biofilm diatoms were scarcely found such that the phytoplankter, Asterionella formosa, which had been flushed from the lake, was the most abundant diatom species encountered from the stones collected at the site. Following turnover, however, the biofilm community reestablished itself and was dominated by Achnanthidium minutissumum in November 2019. Metrics based on diatom community analysis before and after turnover suggest the above lake site was impaired by agriculture (indices indicating high levels of sedimentation and nutrient runoff), but the reservoir did not function as a sediment or nutrient trap. Instead, the downstream sites showed higher impairment than the above lake site.

Introduction

- Impounding a river alters its chemical, ecological and physical composition which can lead to downstream impacts (Winton et al. 2019).
- Diatoms respond to environmental changes (Almeida et al. 2014), thus they are commonly used as indicators of both river and stream water quality (Stevenson et al. 2010).
- The purpose of this study was to continue the work with determining the water quality of the reservoir as it is impacted by one of the main branches of Middle Creek.

Site Description

Walker Lake (Figure 1) is a reservoir impounding the North Branch of Middle Creek located in Snyder County, Pennsylvania. The stream is impacted primarily by agriculture as evidenced by heavily embedded cobble. Walker Lake stratifies during the summer, forming an anoxic hypolimnion in the late summer which persists until turnover in mid-October.

Figure 1. Map of Walker Lake area. Above Walker (**AW**), Below Walker (**BW**), Old Bridge (**OB**), and Swift Run Confluence **(SR + MCN)**.

Methods

- According to the methods of Stevenson and Bahls (1999), stones were collected at all sites in September and October 2019 while Walker Lake was stratified. The second collection was in November 2019 following turnover.
- Samples, when returned to the lab, were cleaned by the following procedure:
  - 5 % acetic acid plus heating
  - Concentrated Potassium Permanganate + concentrated HCl
  - Concentrated (30%) Hydrogen Peroxide + Potassium Dichromate
- Diatom species were identified using a JEOL JSM 6010LV SEM, identification manuals, Diatoms of North America (Diatoms.org) and our gallery of photos.
- Diatom counts performed using the JEOL JSM 6010LV SEM with each site having a 300 valve minimum count.
- Water from each site was collected for alkalinity.
- Using a YSI 556, temperature, oxygen (%saturation), pH, and conductivity were taken.
- Pollution Tolerance Index (PTI) calculated according to Stephenson et al. (2008).

Results

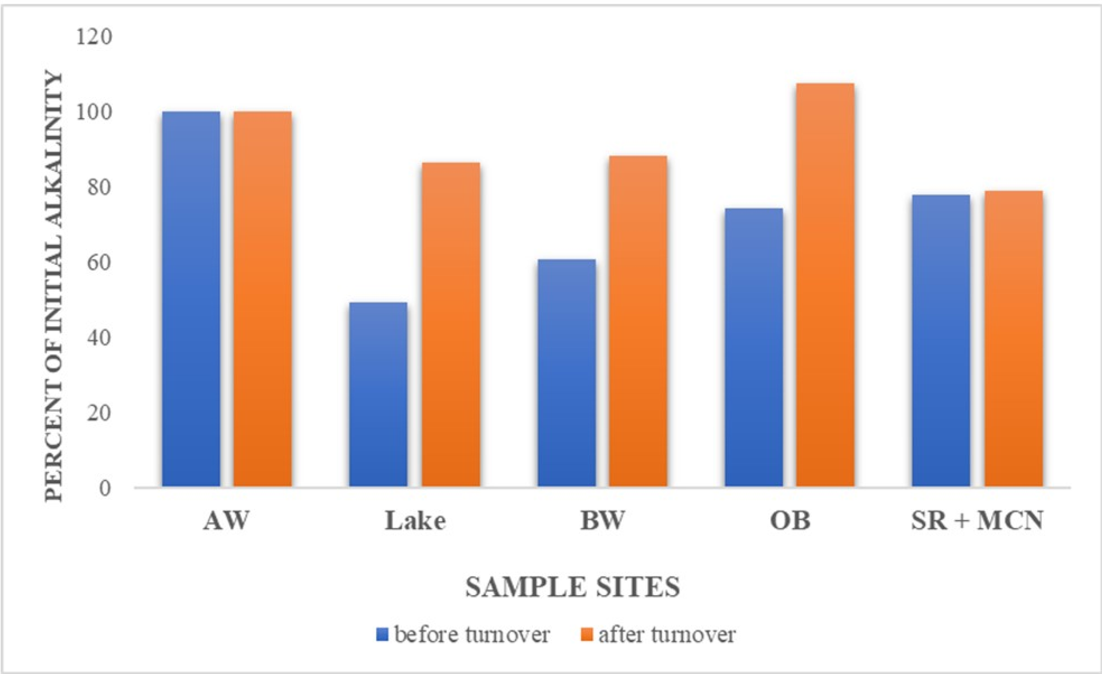

Figure 2. Alkalinity pre (before) and post (after) turnover in microequalivants/liter (µeq/L). The bars represent the percent alkalinity relative to the Above Walker (AW) sample site. Conductivity showed the same trends.

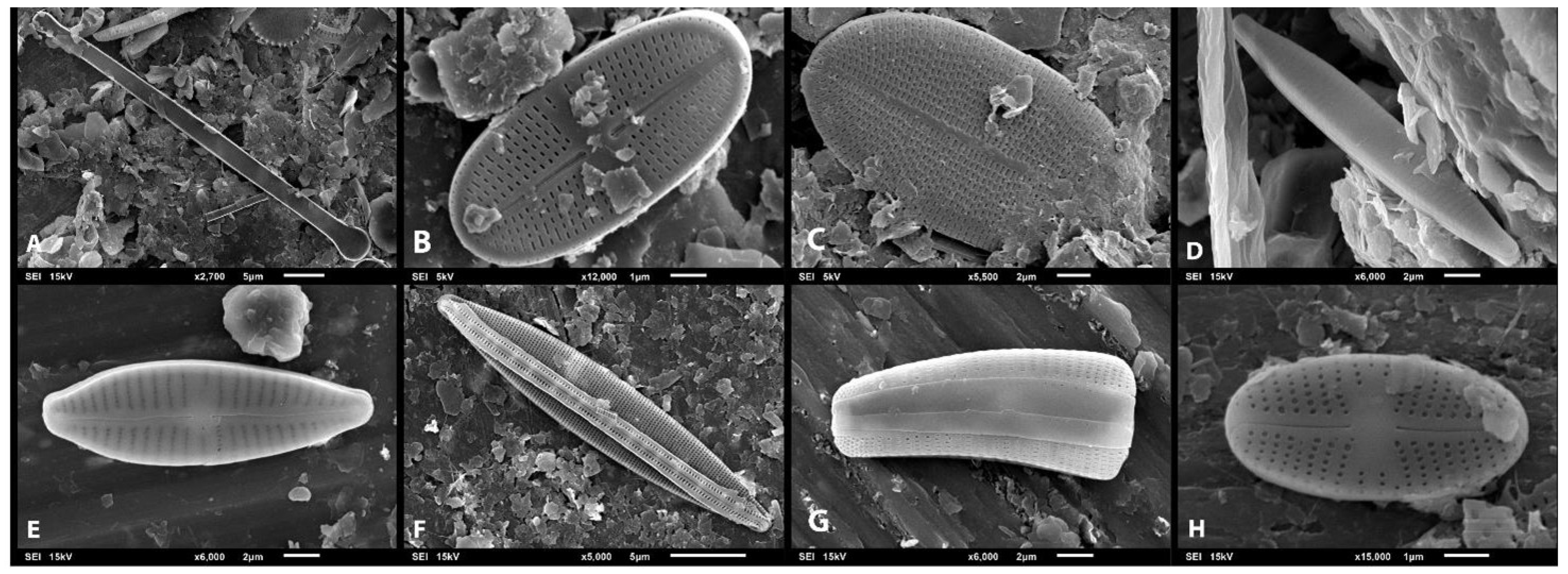

Figure 3. Photomicrographs of the dominant species found in this study. A. *Asterionella formosa,* B. *Achnanthidium minutissimum,* C. *Cocconeis placentula,* D. *Fragilaria vaucheriae,* E. *Gomphonema parvulum,* F. *Nitzschia dissipata,* G. *Rhoicosphenia abbreviata,* and H. *Sellaphora nigri.*

Table 1. All diatom species observed in samples taken from specific locations of Above Walker Lake, Below Walker Lake and Old Bridge (see Figure 1). According to percent occurrence, each cell is color-coded. Results are from counts from the 2019 samples observed in 2020.

>10%
1-10%
<1%
not observed

	AW		BW		OB		SR+MCN	
BINOMIAL	Pre	Post	Pre	Post	Pre	Post	Pre	Post
ACHNANTHIDIUM DEFLEXUM		1.7%	1.1%			0.9%	7.2%	8.9%
ACHNANTHIDIUM EXIGUUM	0.2%							
ACHNANTHIDIUM MINUTISSIMUM	14.2%	19.1%	15.4%	16.4%	21.8%	18.2%	26.9%	23.7%
ADLAFIA BROCKMANNII								
AMPHORA OVALIS	3.9%	0.1%						
AMPHORA PEDICULUS	2.5%	9.0%			1.3%		0.7%	1.0%
ASTERIONELLA FORMOSA			42.0%	21.7%	5.4%	4.1%	1.1%	1.3%
AULACOSEIRA AMBIGUA			0.3%	0.3%				
COCCONEIS PEDICULUS	0.5%	1.0%					7.1%	1.3%
COCCONEIS PLACENTULA	31.7%	5.3%	0.9%	0.2%	6.9%	4.4%	11.7%	8.2%
CYCLOTELLA ATOMUS			0.6%	2.8%	1.1%	0.2%	1.7%	
CYMBELLA AFFINIS				0.1%		0.9%		1.0%
DIATOMA MONILIFORMIS		0.1%				0.5%		7.2%
DISTRIONELLA INCOGNITA		0.2%						
ENCYONEMA APPALACHIANUM	0.4%	1.9%						
ENCYONEMA CAESPITOSUM				0.3%				
ENCYONEMA MINUTUM	0.4%	0.2%		1.1%			0.2%	
ENCYONEMA NEOGRACILE				0.4%				
FRAGILARIA CAPITELLATA		0.2%						
FRAGILARIA CAPUCINA				0.5%				
FRAGILARIA TENERA		0.1%	0.6%	0.8%				0.7%
FRAGILARIA VAUCHERIAE		2.1%	12.5%	4.7%	0.7%	5.9%	0.7%	0.7%
FRAGILARIAFORMA NITZSCHIOIDES						0.8%		
FRAGILARIAFORMA VIRESCENS						1.0%		
FRUSTULIA RHOMBOIDES	0.2%		0.2%			0.2%	0.4%	0.7%
FRUSTULIA SOROR							0.2%	
GOMPHONEIS CALCIFUGA	0.2%							
GOMPHONEIS CLEVEI					0.7%	0.4%	0.7%	0.7%
GOMPHONEMA ANGUSTUM				0.4%				
GOMPHONEMA KOBAYASII	1.1%	1.0%	0.7%	4.4%	0.9%	2.3%		
GOMPHONEMA PARVULUM	0.9%	2.6%	0.7%	11.4%	1.9%	7.2%	2.2%	
GRUNOWIA SINUATA			0.1%		0.2%			
GYROSIGMA ACUMINATUM							2.1%	
HIPPODONTA CAPITATA	0.2%							
LUTICOLA sp.								
MELOSIRA VARIANS	0.2%	0.4%	0.7%	3.1%	0.4%	0.8%	2.3%	4.3%
MERIDION ALANSMITHII		1.8%						
NAVICULA ANTONII						0.5%		
NAVICULA CAPITATORADIATA				0.1%	1.2%		0.7%	0.7%
NAVICULA CRYPTOCEPHALA	0.2%							
NAVICULA CRYPTOTENELLA	0.9%	1.7%		1.5%	0.2%	0.2%	0.2%	
NAVICULA ERIFUGA				0.2%				
NAVICULA GREGARIA	6.5%	4.1%	3.1%	2.3%	7.7%	6.0%	4.0%	5.9%
NAVICULA LANCEOLATA	1.0%	0.2%		0.7%	2.9%	1.1%	4.6%	7.6%
NAVICULA TRIPUNCTATA	1.2%				1.1%	0.2%	2.2%	3.3%
NAVICULA VENETA							0.4%	
NITZSCHIA ACICULARIS			0.2%		0.2%	0.2%	0.5%	
NITZSCHIA AMPHIBIA			0.4%					
NITZSCHIA DISSIPATA	6.0%	6.1%	2.1%	1.6%	2.4%	16.1%	2.0%	1.3%
NITZSCHIA PALEA	4.3%	2.8%	0.9%	0.7%	4.0%	9.9%	7.4%	4.3%
RHOICOSPHENIA ABBREVIATA	18.0%	25.0%	2.4%	9.4%	32.4%	10.1%	10.3%	15.5%
SELLAPHORA NIGRI	4.3%	11.8%	1.5%	7.0%	5.4%	1.5%	1.7%	
SELLAPHORA PUPULA		0.1%		0.3%				
STEPHANOCYCLUS MENEGHINIANA	0.1%			0.1%				
STEPHANODISCUS MINUTULUS			9.7%	5.6%	1.1%	0.9%	0.1%	
STEPHANODISCUS PARVUS			3.9%	1.7%	0.1%			
SURIRELLA AMPHIOXYS	0.2%							
SURIRELLA ANGUSTA	0.3%	0.2%				1.2%		0.7%
SURIRELLA MINUTA		1.0%				4.1%	0.7%	1.3%
UNKNOWN	0.2%	0.1%						
Unique Taxa	3	3	1	4	1	1	3	0
Dominant Taxa	3	3	3	3	2	3	3	2
Common Taxa	7	10	7	12	13	11	13	14
Rare Taxa	16	14	12	14	9	15	12	6
Total Taxa	26	27	22	29	24	29	28	22

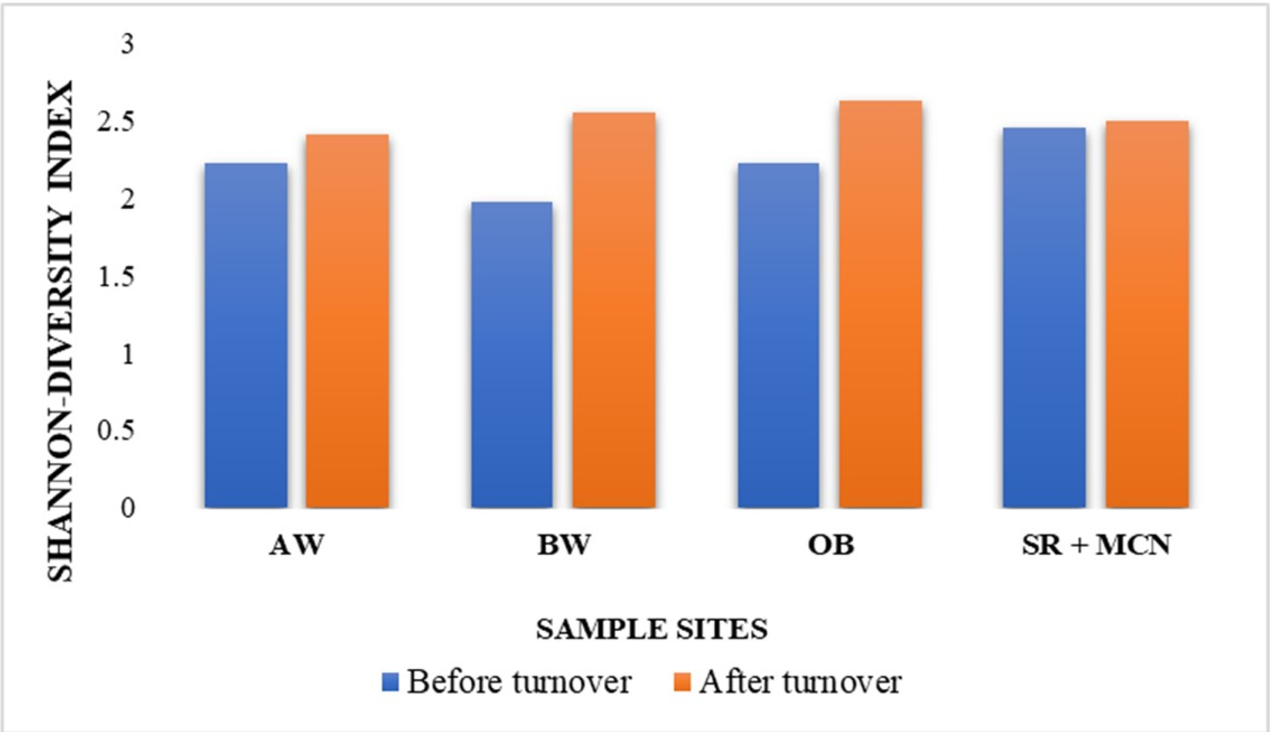

Figure 4. Shannon-diversity index (SDI) for all three sites before and after turnover.

Table 2. Diatom generated metrics for before (pre) turnover and after (post) turnover at each sample site.

	ABOVE WALKER		BELOW WALKER		OLD BRIDGE		SWIFT RUN	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
PTI	2.714	2.572	2.736	2.468	2.628	2.425	2.628	2.737*
SED INDEX	20.591	16.108	6.748	7.104	19.714	39.695	28.273	25*
TOTAL P	8.068	7.855	2.331	6.369	7.27	7.57	4.889	N/A*
TOTAL N	8.131	8.396	6.957	8.64	7.342	7.993	4.812	N/A*

Discussion

- Loss of alkalinity is evident in Walker Lake and downstream when the impoundment is stratified. It recovers somewhat following turnover (Figure 2). Conductance followed the same trend.
- Table 1 lists the diatom species found at each site before and after turnover. The list includes planktonic taxa that flushed from the reservoir, particularly *Asterionella formosa* before turnover. A monoraphid dominant throughout all the sample sites and sample dates was *Achnanthidium minutissium.* Other dominant species included *Cocconeis placentula, Fragilaria vaucheriae, Gomphonema parvulum, Nitzschia dissipata, Rhoicosphenia abbreviata,* and *Sellaphora nigri* (Figure 3).
- Shannon Diversity increased at each site following turnover (Figure 4) because species richness increased. Swift Run had very similar SDI values both before and after turnover.
- The stream above the lake appears to be impaired and the diatom inferred water quality does not improve downstream (Table 2). The Pollution Tolerance Index (PTI) remained constant (2.42-2.74) at the downstream sites. Furthermore, diatoms characteristic of nitrogen and phosphorus enrichment did not change from above Walker to below Walker sites.
- The sedimentation index suggests high levels of sedimentation above Walker, at Old Bridge, and at the Swift Run Confluence. The site immediately below the dam had a sedimentation index that was low due to high levels of flushing below the dam (Table 2).
- We conclude that the primary impact on the North Branch of Middle Creek is agriculture, and the reservoir, even when stratified has little influence on the stream.

Acknowledgments

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Literature Cited

Almeida, S.F.P, C. Elias, J. Ferreira, E. Tornés, C. Puccinelli, F. Delmas, G. Dörflinger, G. Urbanič, S. Marcheggiani, J. Roseberry, L. Mancini, and S. Sabater. 2014. Water quality assessment of rivers using diatom metrics across Mediterranean Europe: A methods intercalibration exercise. Science of the Total Environment 476-477: 768-776.

Stevenson, R.J. and L.L. Bahls. 1999. Periphyton Protocols. In: Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Stevenson, R. J., Y. Pan, and H.V. Dam. 2010. Assessing environmental conditions in rivers and streams with diatoms. In: The Diatoms: Applications for the Environmental and Earth Sciences, 2nd ed.

Stevenson, R. J., Y. Pan, K. M. Manoylov, C. A. Parker, D. P. Larsen, and A. T., Herlihy. 2008. Development of diatom indicators of ecological conditions for streams of the western US. Journal of the North American Benthological Society, 27(4):1000-1016.

Winton, R.S., E. Calamita, and B. Wehrli. 2019. Reviews and syntheses: Dams, water quality and tropical reservoir stratification. Biogeosciences 16(8): 1657-1671.