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Nutrient Enrichment Study Data from the Upper, Middle, and Lower Sections of the Non-Tidal Delaware River, 2009

Data Series 555

U.S. Department of the Interior
U.S. Geological Survey

Cover:

Matlock periphytometer deployed at the Middle Delaware River near Bushkill, Pa. (Spackman's Island). Photograph taken just before recovery of the arrays. (Photograph by Erik Silldorff, Delaware River Basin Commission, September 22, 2009.)

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KEN SALAZAR, Secretary

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Conversion Factors, Abbreviations, and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Area	
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (in^2)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in micrograms per liter (µg/L) or milllimohls (mM)

Nutrient Enrichment Study Data from the Upper, Middle, and Lower Sections of the Non-Tidal Delaware River, 2009

By Robin A. Brightbill,[1] Robert Limbeck,[2] Erik Silldorff,[2] and Heather L. Eggleston[1]

Abstract

The Delaware River Basin Commission is charged with establishing water-quality objectives for the tidal and non-tidal portions of the Delaware River, which include developing nutrient standards that are scientifically defensible. The U.S. Geological Survey, in cooperation with the Delaware River Basin Commission and the Academy of Natural Sciences, studied the effects of nutrient enrichment in the upper, middle, and lower sections of the non-tidal Delaware River. Algal samples were collected from the natural habitat using rock scrapes and from the artificial nutrient enrichment samplers, Matlock periphytometers. The knowledge gained from this study is to be used in helping determine appropriate nutrient criteria for the Delaware River in the oligotrophic, mesotrophic, and eutrophic sections of the river and is a first step toward gathering data that can be used in selecting nutrient effect levels or criteria thresholds for aquatic-life use protection. This report describes the methods for data collection and presents the data collected as part of this study.

Introduction

Nutrients, such as nitrogen and phosphorus, are needed for healthy algal growth and primary production in streams and rivers. Nutrient concentrations above natural background levels can lead to shifts in the algal community that can affect aquatic life and promote growth of excessive amounts of algae. Excessive algae growth (algal blooms) causes streams to be esthetically unpleasant as well as causing large biomass accumulations that lead to nocturnal oxygen depletion that can negatively affect fish and macroinvertebrates (Stevenson and others, 1996; Stevenson and Lowe, 1986; Sze, 1986). The Clean Water Action Plan of 1998 (U.S. Environmental Protection Agency, 1998) is designed to protect public health and restore waterways by setting strong goals and providing States, communities, and farmers with the tools and resources to protect the waters of the United States. The U.S. Environmental Protection Agency (EPA) was tasked with developing a plan to address nutrient enrichment in waters (Buck and others, 2000) and setting nutrient criteria for rivers and streams nationwide (U.S. Environmental Protection Agency, 1998).

As part of the EPA initiative, the Delaware River Basin Commission (DRBC) was charged with establishing water-quality objectives for the tidal and non-tidal portions of the Delaware River. DRBC is presently implementing a strategy to scientifically develop nutrient criteria for the Delaware River and its estuary (Santoro and Limbeck, 2008). Part of that strategy is to investigate the effects of nutrient enrichment on aquatic life of the Delaware River and to gather a weight of evidence toward establishing nutrient-concentration thresholds. Nutrient concentrations are generally well described in the Delaware River, but the effects of nutrient enrichment on aquatic life are not well known. The U.S. Geological Survey (USGS) cooperated with the DRBC and the Academy of Natural Sciences (ANSP) to study the effects of nutrient enrichment in the upper, middle, and lower sections of the non-tidal Delaware River. This study is a first step toward gathering data that can be used in selecting nutrient effect levels or criteria thresholds for aquatic-life use protection. The methods used to gather such data and the data from this study are presented here.

Site Selection

The entire non-tidal Delaware River is generally wide, shallow, and gravel and cobble bottomed, and primary production is dominated by periphyton. The diatom community of the Delaware River experiences a strong gradient in composition from upstream to downstream, shifting from a community dominated by oligotrophic diatoms upstream to one dominated by eutrophic diatoms downstream (Limbeck and Smith, 2007). Diatom-community metrics may display a strong response to nutrient addition, enabling their utility as site-specific biological critera for protection of aquatic life from increased nutrient concentrations and loadings.

Three areas along the Delaware River were chosen for study. These areas are in geologically and ecoregionally

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distinct sections of the river. The upper section passes through the Appalachian Plateau of the southern New York State Catskill Mountains and is sparsely populated. The river in this section is nutrient poor with mean concentrations of total phosphorus (TP) and total nitrogen (TN) of approximately 29 and 495 µg/L, respectively (Santoro and Limbeck, 2008). The middle section passes through the Ridge and Valley physiographic region and is experiencing rapid population growth outside of a protected National Recreation Area corridor. The river in this section is still nutrient poor (mean TP concentration is 27 µg/L and mean TN concentration is 412 µg/L) but is at a greater risk for nutrient enrichment from cultural eutrophication as the population expands. The lower section passes through a limestone band and the populated and industrialized Lehigh Valley and Piedmont region. The median nutrient concentrations for this section of the river are 100 µg/L for TP and 1,410 µg/L for TN. Specific site locations sampled for algal growth using the periphytometers are listed in table 1 and are shown on figure 1.

Sample Collection and Laboratory Analyses

Sample collection consisted of natural algal habitat (rock) and the nutrient enrichment artificial samplers (Matlock periphytometers). The analyses of the rock samples were used to characterize the natural background algal species and density of each section of the river. The results from the Matlock periphytometers examined possible changes to the algal biomass and species composition if nutrient enrichment were to alter the different sections of the river. Water-quality and habitat data also were collected as part of the study.

Matlock Periphytometer Deployment

Matlock periphytometers were assembled according to the method described by Matlock and others (1998) and a diagramed description provided to the USGS by Marty Matlock, associate professor of biology and agricultural engineering at the University of Arkansas (written commun., Dec. 27, 2007). A total of 12 bottles (250 mL) were filled with either ambient water (3 bottles) or a solution consisting of a mix of ambient water and a nutrient concentrate (9 bottles). The nutrient concentrates were prepared by ANSP. Three solutions of ambient water and nutrient concentrates were used: a concentrated nitrogen solution (2.6 mM $NaNO_3$), a concentrated phosphorus solution (0.65 mM Na^2HPO_4), and a concentrated nitrogen and phosphorus mixed solution of 2.6 mM nitrogen and 0.65 mM phosphorus.

After the bottles were filled, a 47-mm nylon membrane was placed over the opening of the bottle, a 37-mm glass-fiber filter was placed over the nylon membrane, and the bottle cap with a hole drilled through it was screwed into place over the membrane and filter. The filters used for algal growth ash free dry weight analysis were preashed and weighed before they were placed on the appropriate bottles. The weights of the filters were recorded on the field sheets and provided to ANSP. The pre-weight was subtracted from the final ashed weight of the algal coated filter for a final weight that would reflect the biomass only (Paul Kiry and David Velinsky, Academy of Natural Sciences, written commun., Feb. 7, 2008). To reduce the chance that invertebrates could colonize on the filter and eat the algal crop, an aluminum wire screen (about 4 in^2 of window screen) was placed over the capped end of the bottle and held in place with a zip-tie. The bottles were attached to a 3 ft by 3 ft piece of fencing using zip-ties.

A partial Latin Square design was used for bottle placement on the fencing to minimize positional effects. One row was randomly removed from the typical Latin Squares, and some post-randomization edits were done to two sites to remove the systematic effect of a single treatment being in the same lateral position in a given array. This resulted in a design of three rows by four columns. A diagram illustrating the arrangement of periphytometers at each site is shown in appendix 1.

The Matlock periphytometers were deployed on transect locations (table 1) and were placed at least 10 m from the bank with a minimum of 5 m spacing in approximately 2 to 3 ft deep glides having similar velocities (1.5 to 2.5 ft^3/s). Each

Table 1. Names and locations of sampling sites in the upper, middle, and lower sections of the Delaware River, 2009.

[USGS, U.S. Geological Survey; DRBC, Delaware River Basin Commission]

USGS station name	USGS station identifier	DRBC station name	DRBC station identifier	Latitude	Longitude	Location
Delaware River near Milanville, Pa.	01427725	Upper Delaware River near Milanville, Pa. (Castillo del Rio)	DRBC2935	41.64772	-75.04939	Upper
Delaware River near Egypt Mills, Pa.	01439250	Middle Delaware River near Bushkill, Pa. (Spackman's Island)	DRBC2336	41.10439	-74.98422	Middle
Delaware River near Upper Black Eddy, Pa.	01458200	Lower Delaware River near Raubsville, Pa. (Upper Black Eddy)	DRBC1666	40.62486	-75.18887	Lower

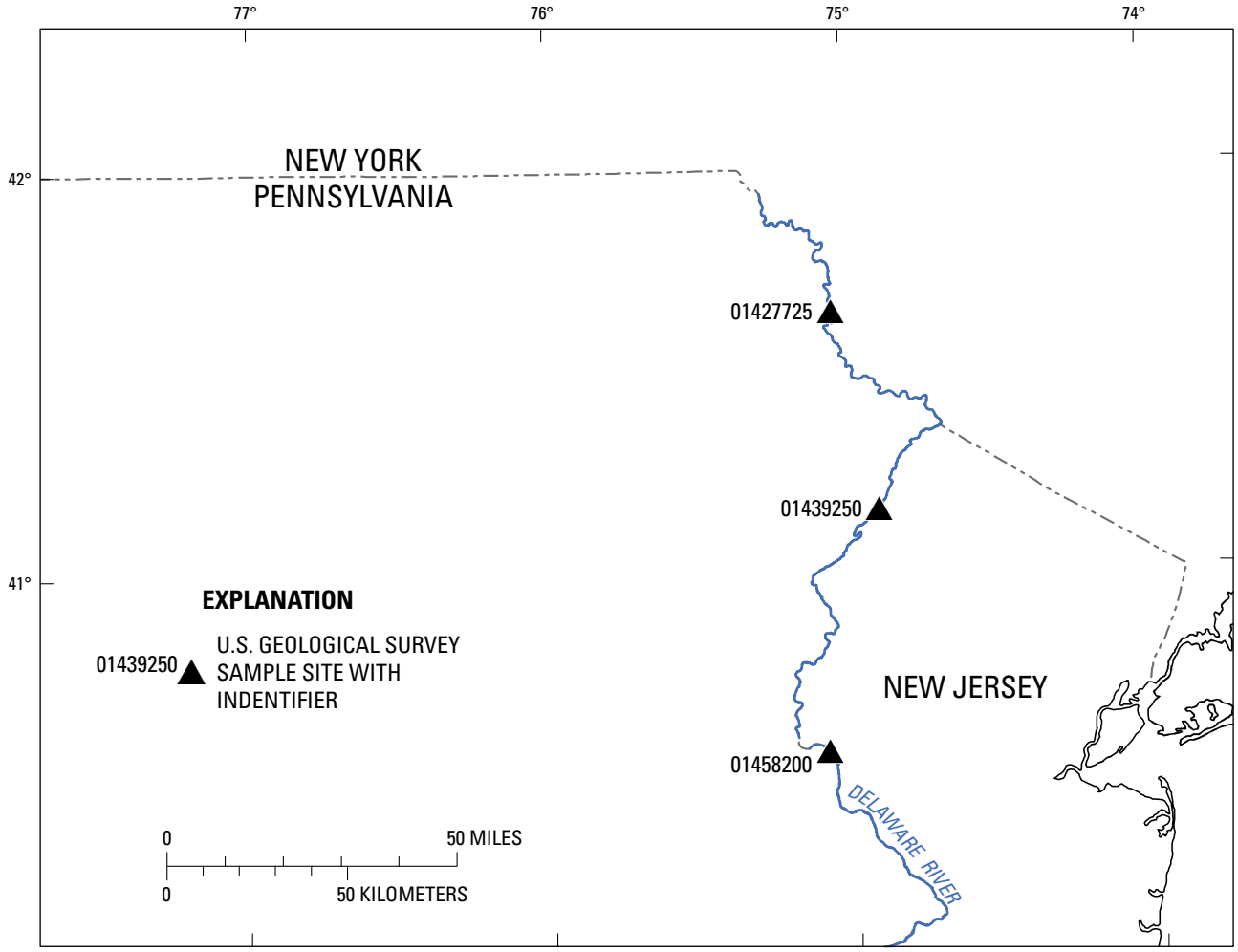

Figure 1. Locations of sampling sites in the upper, middle, and lower sections of the Delaware River, 2009.

periphytometer had zero percent canopy cover as measured using a densiometer. The periphytometers were placed in cleared areas of the stream bottom so that the filters would be even in depth with the surrounding rocks where periphyton grow, and small rocks were placed around the fencing to help the periphytometers stay in place. Rebar (2 ft in length) were driven through the fencing in the two upstream corners of the array and into the river bottom. The periphytometer was attached to the rebar using zip-ties. This was a slight modification from the original design but was necessary to avoid boating and tubing traffic in the Delaware River and to secure the periphytometers to the river bottom. Global position of each periphytometer was recorded.

Two sets of periphytometers were placed in late July 2009, one set in the lower section of the Delaware River and one in the middle section of the Delaware River. The third set of periphytometers was not placed in the upper section of the Delaware River because of heavy rains that caused higher than normal flows and siltation. This heavy rain caused the experiment to be postponed. The first two sets of periphytometers were retrieved after the water receeded enough to get back in the river to pull them. These periphytometers were cleaned and remade so they could be set again. No data were retrieved from the periphytometers, but the background top-rock scrape samples were analyzed and the data are part of the broader algal database of DRBC. These July data will not be part of the analysis of the periphytometer work (appendix 2, Ambient Data). The new deployment dates were August 26, 2009, for the upper section; September 8, 2009, for the middle section; and September 10, 2009, for the lower section.

Natural Water-Quality, Habitat, and Algal Sampling

Dissolved oxygen, specific conductance, pH, and water temperature were measured with handheld meters at each site at the time of deployment, and nitrogen and phosphorus grab samples were collected, one week during deployment and again at retrieval. The nitrogen and phosphorus samples were sent overnight to ANSP for analysis (O'Dell and others, 1993). Velocity, depth, and light attenuation were measured at 14 locations around each periphytometer (appendix 1) when they were deployed. The July data for the lower and middle sections of the river are reported here and will be used as background information for the river. Habitat was assessed using the Rapid Bioassessment method described in Barbour and others (1999) during deployment only. The presence of *Podostemum sp.* and *Corbicula sp.* were noted only during deployment. DRBC collected periphyton from eight rocks near each periphytometer and used the top-rock scrape method to collect samples for chlorophyll *a* (chl*a*), ash free dry mass (afdm), and taxonomy at both deployment and retrieval of the periphytometers. This was done to establish a background concentration and species present record of the natural periphyton at each transect of the river where the periphytometers were deployed (Fisklin and others, 2007).

Nutrient Enrichment Artificial Sampler Retrieval

The periphytometers were retrieved from the upper section on September 9, 2009; from the middle section on September 22, 2009; and from the lower section on September 23, 2009. Dissolved oxygen, specific conductance, pH, and water temperature were measured using handheld meters during the retrieval process, and nutrients samples were collected in the river near where the periphytometers had been placed. At the areas of the periphytometers, periphyton were sampled from the natural substrate and analysed for chl*a*, afdm, and taxonomy. These natural substrate data will be used by DRBC for comparison to the control samples on the periphytometer.

The periphytometer filters were collected, preserved, and sent to ANSP for analysis. One filter from each solution in the array was analyzed for afdm, one for chl*a*, and one for taxonomy. The filters for afdm and chl*a* were placed in petri dishes, and the petri dishes were wrapped in aluminum foil, placed in a plastic bag with a label containing sampling information, and placed on dry ice. The taxonomy filters were loosely rolled and placed in a small vial containing formaldehyde for preservation purposes.

Algal Processing

ANSP determined chl*a* (Velinsky and DeAlteris, 2002) and afdm (Kiry and others, 2000), which incorporated the protocols set by EPA (1983) and the Welschmeyer (1994) method of analysis of chl*a* and afdm biomass. The taxonomy of the samples was determined using methods described in Charles and others (2002) for the identification, enumeration, documentation, and measurement of soft algae and diatoms. Because the sample was grown on glass microfiber filters, modifications of the protocols for identification were necessary. Modifications included taking photos of the filters to record the relative abundance of algal growth (Frank Acker, Academy of Natural Sciences, written commun., May 3, 2010). An analyst then picked off select species of soft algae to identify under low- and high-power magnification. All cells were then returned to the vials along with the filters.

Finally, the filters were scraped to remove material for diatom analysis by placing the filters in a glass Petri dish and viewing under a dissecting microscope. Dissecting needles were used to individually pick off filamentous algae and scrape off clumps of brown deposits (diatoms). As many of the cells as possible were removed from the filters, added to the liquid portion of the sample in a beaker, diluted, and allowed to settle overnight. Once in solution, the slides were prepared according to the protocols in Charles and others (2002). Two different types of information were generated from these slides. One analysis of the slide was for diatom identification and enumeration, and the other was for a measure of cell biovolumes. Both analysis results are presented in appendix 3.

Quality Assurance

Two split biomass samples were analyzed from the rock scrapes. Chl*a* was run on one of the samples, and the standard error was 10 percent. Afdm was run on both samples. One sample had a standard error of 4 percent and the other 34 percent. Data are presented in appendix 2.

Biological and Environmental Data

Periphyton biomass indicator data, periphyton taxonomy, residual and ambient nutrients, and the ambient water quality are presented in appendixes 2–5 for the upper, middle, and lower sections of the non-tidal Delaware River. A brief description of the appendixes is shown in table 2.

Looking at the background data (rock scrapes), the proportion of high nutrient optima diatoms increases from upstream to downstream as nutrients in the ambient water increase. Low nutrient optima diatoms decrease from upstream to downstream as the high nutrient optima diatoms replace the low nutrient optima diatoms. Optima values are from Potapova and Charles (2007).

The periphytometer work indicates that the upper section of the river is phosphorus limited and that increases in phosphorus will increase algal biomass amd the number of high nutrient optima diatoms. The middle section of the river is also phosphorus limited and possibly nitrogen limited and biomass and high optima nutrient diatoms increased with addition of these nutrients. The lower section may be sufficiently nutrient rich that additional nutrients had no effect.

Summary

The USGS cooperated with the DRBC and the ANSP to study the effects of nutrient enrichment in the upper, middle, and lower sections of the Delaware River. Samples of periphyton were collected using rock scrapes of the natural algal habitat and the Matlock periphytometer, a nutrient enrichment artificial sampler. Results from this study will be used to help determine appropriate nutrient-criteria levels for the three distinct sections of the river for the protection of aquatic life. Results are contained in the appendixes of this report.

Acknowledgments

This project was done in cooperation with Paul Kiry of the Academy of Natural Sciences. A special thank you to Russell Ludlow of the U.S. Geological Survey for his assistance in the field. Funding for this work was from the U.S. Environmental Protection Agency Region III Nutrient Criteria Development Program.

Table 2. Brief description of the data sets collected and analyzed as part of the nutrient enrichment study in the upper, middle, and lower sections of the Delaware River, 2009.

Data set	Brief description
Periphyton biomass	Periphyton biomass indicator for rock scrapes and periphytometer filters and nutrient results for ambient stream samples and periphytometer bottles (appendix 2)
Periphyton taxonomy	Periphyton taxonomy results for ambient rock scrapes and periphytometer filters (appendix 3)
Water quality	Stream water-quality measurements (appendix 4)
Habitat	Stream water velocity, light attentuation, rapid bioassessment, and other observational results (appendix 5)

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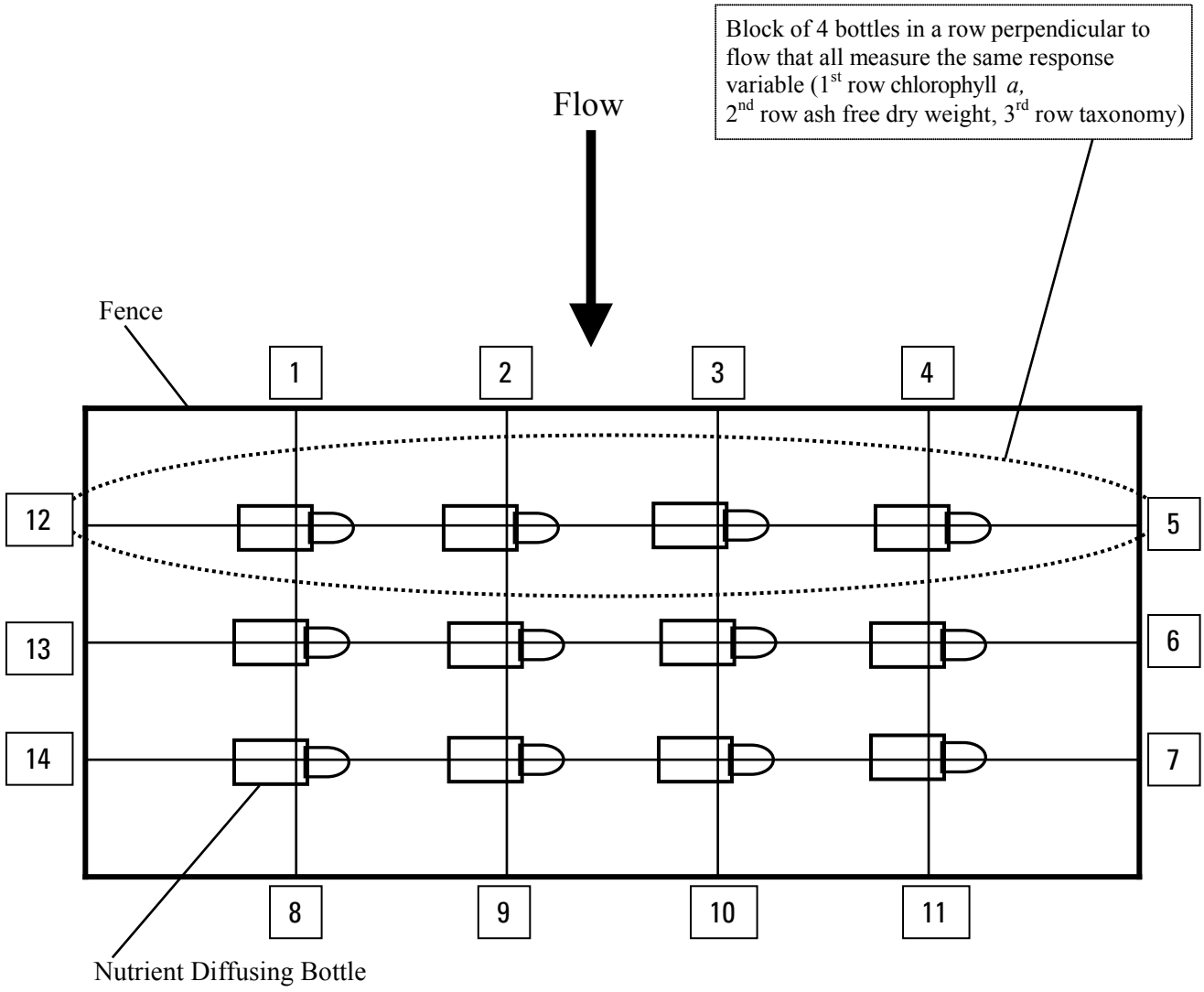
Appendix 1. Set-up and blocking design for Matlock periphytometers and locations for velocity, depth, and light intensity measurements taken around the periphytometers at the time of deployment.



Layout for upper site, 01427725, Delaware River near Milanville, Pa. (Upper Delaware River near Milanville, Pa. (Castillo del Rio) DRBC2935)

[Top row of bottles and filters were analyzed for chlorophyll *a*, middle row for ash free dry weight, and the bottom row for taxonomy. This was consistent for all arrays at all study reaches]

#1	Nitrogen and phosphorus	Control	Phosphorus	Nitrogen
	Phosphorus	Nitrogen and phosphorus	Control	Nitrogen
	Control	Phosphorus	Nitrogen	Nitrogen and phosphorus

#2	Phosphorus	Nitrogen and phosphorus	Nitrogen	Control
	Nitrogen	Phosphorus	Nitrogen and phosphorus	Control
	Phosphorus	Control	Nitrogen and phosphorus	Nitrogen

#3	Nitrogen	Phosphorus	Control	Nitrogen and phosphorus
	Nitrogen and phosphorus	Control	Nitrogen	Phosphorus
	Nitrogen	Nitrogen and phosphorus	Phosphorus	Control

Layout for middle site, 01439250 Delaware River near Egypt Mills, Pa. (Middle Delaware River near Bushkill, Pa. (Spackman's Island) DRBC2285)

[Top row of bottles and filters were analyzed for chlorophyll *a*, middle row for ash free dry weight, and the bottom row for taxonomy. This was consistent for all arrays at all study reaches]

#1	Nitrogen and phosphorus	Phosphorus	Nitrogen	Control
	Phosphorus	Control	Nitrogen and phosphorus	Nitrogen
	Phosphorus	Nitrogen	Nitrogen and phosphorus	Control

#2	Nitrogen	Control	Nitrogen and phosphorus	Phosphorus
	Control	Phosphorus	Nitrogen	Nitrogen and phosphorus
	Control	Nitrogen and phosphorus	Nitrogen	Phosphorus

#3	Phosphorus	Nitrogen	Control	Nitrogen and phosphorus
	Nitrogen and phosphorus	Nitrogen	Control	Phosphorus
	Nitrogen	Control	Phosphorus	Nitrogen and phosphorus

Layout for Lower site, 01458200 Delaware River near Upper Black Eddy, Pa. (Lower Delaware River near Raubsville, Pa. (Upper Black Eddy) DRBC1666)

[Top row of bottles and filters were analyzed for chlorophyll *a*, middle row for ash free dry weight, and the bottom row for taxonomy. This was consistent for all arrays at all study reaches]

#1	Phosphorus	Nitrogen and phosphorus	Control	Nitrogen
	Control	Nitrogen and phosphorus	Phosphorus	Nitrogen
	Nitrogen	Phosphorus	Control	Nitrogen and phosphorus

#2	Control	Nitrogen	Phosphorus	Nitrogen and phosphorus
	Nitrogen and phosphorus	Phosphorus	Nitrogen	Control
	Control	Nitrogen	Nitrogen and phosphorus	Phosphorus

#3	Nitrogen	Phosphorus	Nitrogen and phosphorus	Control
	Nitrogen	Control	Nitrogen and phosphorus	Phosphorus
	Phosphorus	Nitrogen and phosphorus	Nitrogen	Control

Prepared by the West Trenton Publishing Service Center.

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