Report for 2005MN118B: A Rapid Bioassessment Approach for Integrating Biological Data into TMDL Development for Organic Enrichment of Streams in Urbanizing Watersheds

Publications

- There are no reported publications resulting from this project.

Report Follows

A Rapid Bioassessment Approach for Integrating Biological Data into TMDS Development for Organic Enrichment of Streams in Urbanizing Watersheds

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Introduction

The Federal Pollution Control Act Amendments of 1972 (PL 92-500), as supplemented by the Clean Water Act of 1977 and the Water Quality Act of 1987 (in conjunction with more recent amendments) serve as the foundation for protecting the quality of our surface waters. Present-day implementation of Section 303d of the Clean Water Act focuses on ambient water quality standards, and requires states (1) to identify surface waters that are not meeting ambient water quality standards appropriate for their designated use categories and (2) to define the pollutants and their sources that are responsible for non-attainment of the ambient water quality standards. Section 303d further requires states to establish Total Maximum Daily Loads (TMDL) for pollutants impairing the surface waters and to develop strategies for reducing both point and non-point sources of the pollutants in order for the non-attaining waterbodies to meet ambient water quality standards.

Biological data are typically integrated into the above process as "front-end" input, being used (1) to assist in development of designated use categories and (2) in monitoring efforts to ensure that ambient water quality standards are met. However, prediction of biological responses that are likely to result from implementation of TMDL plans is not a fundamental element of the TMDL process. In a recent overview of the TMDL approach to water quality management requested by the US Congress, the National Research Council (2000, the full is text available on line at http://nap.edu/openbook/0309075793/html/6.html) made several recommendations for integration of biological data into the TMDL process. Among the recommendations, the report states "*EPA should promote the development of models that can more effectively link environmental stressors (and control actions) to biological responses*" and "*Monitoring and data collection programs need to be coordinated with anticipated water quality and TMDL modeling requirements*". This proposal is to employ a newly tested rapid bioassessment technique developed for assessing organic enrichment in urban areas of Minnepolis/Saint Paul (Minnehaha Creek) in a second watershed (Vermillion River catchment) that is undergoing rapid urban development.

Incorporation of biological monitoring and numeric biological criteria by states into water quality standards has been a slow process. As of 1999, only two states had incorporated explicit monitoring and biocriteria into to their statutes defining water quality standards, and fifteen others were at various stages of developing and codifying biological parameters into their standards (Karr and Chu, 1999). At the urging of the National Academy of Sciences (2001) several additional states have more recently picked up momentum in this regard, but most cite shortages of federal, state and local sources of funding along with staffing deficiencies as impeding their progress. The long turn-around time for comprehensive biological surveys is also cited as contributing to the problem. Development of Rapid Bioassessment Protocols (e.g., Plafkin *et al.* 1989, Barbour *et al.* 1999) have represented attempts to reduce both costs and turn-around times for benthological surveys.

Previously, I was involved with the U. S. EPA Region VII in Kansas City to develop an alternative protocol using Chironomidae (Ferrington, 1987) as the basis for a Rapid Bioassessment Protocol (RBP). Our intent was to develop a protocol that could be employed in highly disturbed urban streams and rivers where the more standard procedures and metrics, at that time being developed by Plafkin *et al.* (1989), showed little promise for application due to the lack of biodiversity of Plecoptera, Ephemeroptera and Trichoptera. Chironomidae (Diptera) often predominate in highly disturbed urban streams (Ferrington 1990, Ferrington *et al*. 1991), increasing in relative abundance and richness as the degree of pollutant stress increases. Barbour *et al.* (1999) subsequently revised some of the protocols to more effectively utilize Chironomidae in a few of the metrics, but the potential for their cost-efficient use remains largely under-developed. In this project I employed a methodology for cost-effective analysis of Chironomidae for a rapidly urbanizing area, the Vermillion River watershed, with the objective of providing data to be integrated into setting goals for TMDL's related to organic enrichment in the watershed.

Methods

Description of Methodology for Cost-effective Analysis of Chironomidae in the Vermillion River Watershed- In this project collections of surface floating pupal exuviae (SFPE) were used to generate information about chironomid communities at 10 sites longitudinally within the Vermillion River watershed. Since this monitoring technique is little known among and poorly understood by water quality managers in the United States, I provide a detailed description of the technique in the following paragraphs.

Although not widely used in ecological investigations in the United States, collecting SFPE is not a new approach for gathering information about Chironomidae communities. It was first suggested by Thienemann (1910), but only occasionally used in taxonomic and biogeographic studies (Thienemann 1954, Brundin 1966) or ecological studies (Humphries 1938) until more recently. During the last 35 years, however, there has been increasing use of pupal exuviae collections in chironomid studies. Reiss (1968) and Lehmann (1971) used collections SFPE to supplement their larval collections when investigating Chironomidae community composition. In Western Europe and England collections of SFPE have been used extensively for surface water quality monitoring (McGill *et al.* 1979, Ruse 1995a, b; Ruse & Wilson 1984, Wilson 1977, 1980, 1987, 1989; Wilson & Bright 1973, Wilson & McGill 1977, Wilson & Wilson 1983). In North America the methodology has been successfully used in studies of phenology (Coffman 1973, Boerger 1981, Wartinbee & Coffman 1976), diel emergence patterns (Coffman 1974), ecology and community composition (Blackwood *et al*. 1995, Chou *et al*. 1999, Ferrington 1998, 2000, Ferrington *et al*. 1995, Kavanaugh 1988), microbial decomposition (Kavanaugh 1988), assessment of effects of point sources of enrichment (Coler 1984, Ferrington & Crisp 1989), non-point pesticide effects (Wright & Ferrington 1996), and effects of agricultural practices (Barton *et al*. 1995). In England and the United States SFPE collections have been used to study water and sediment quality (Ruse & Wilson 1984, Ruse *et al*. 2000, Ferrington 1993b), and used in Australia for measuring phenology (Hardwick *et al.* 1995) and effects of stream acidification on Chironomidae (Cranston *et al*. 1997). The following paragraphs briefly describe aspects of the methodology common to most of the above applications.

Chironomid larvae live in soft sediments or on rocks and interstitial materials in stream beds, where they generally attain densities of 1000 or more larvae per square meter in healthy stream systems (Coffman & Ferrington 1995), and often more than 30,000 larvae per square meter in organically enriched streams (Ferrington 1990). Upon completion of the larval life they attach themselves with silken secretions to the surrounding substrates and pupation occurs. When the developing adult matures the pupa frees itself from the silken chamber and swims to the surface of the water where the adult emerges from within the pupal skin (or exuvia). The exuvia fills with air and by virtue of an outer waxy layer of the cuticle (which has non-wettable properties) it remains floating on the water surface until bacteria begin to decompose the wax layer. Floating exuviae are concentrated by stream currents into eddy areas or into regions such as slack water areas downstream of rocks or points where riparian vegetation or fallen trees contact the water surface. By collecting exuviae from these "natural" collection points, one can rapidly evaluate the emergence of Chironomidae from a broad spectrum of microhabitats in the stream. Emergence frequencies are then calculated for all species in the SFPE sample.

Field collection of SFPE is accomplished by dipping an enameled pan into the water downstream of areas where pupal exuviae accumulate. Water, detritus and floating pupal exuviae flow in as one edge of the pan is dipped beneath the surface of the water. After the pan has filled with water, the contents are passed through a U.S. Standard Testing Sieve with aperture of 125 microns. Detritus and exuviae are retained by the sieve. The entire procedure of dipping and sieving is repeated until a large amount of detritus and exuviae is accumulated in the sieve. Contents of the sieve are then transferred to a sample jar and field preservative of 80% ethanol added, along with a sample label. Exuviae are sorted from detritus in the laboratory under 12X magnification to insure all specimens are found and removed. It has been my experience that 10 minutes of collecting provides sufficient sample size for impact assessments in streams moderately to severely impacted by organic enrichment in eastern Kansas, with samples often containing several hundred to a thousand or more exuviae. The SFPE protocol is accepted as a Standard Operating Procedure (SOP) and a Rapid Bioassessment Protocol for water quality investigations by Region VII of the U.S. Environmental Protection Agency (Ferrington 1987).

Recently published identification guides for identifying pupal exuviae by Coffman and Ferrington (1984, 1995), Wiederholm (1986), Wilson and McGill (1982) and Langton (1991) have facilitated more extensive use of the method and easier adoption by monitoring agencies.

Sampling Design: This project was designed as a one-year study and initiated in March 2005. Ten sample sites were selected after consultation with MCES and Dakota County scientists. Eight sites were selected to bracket areas known to have contrasting water quality conditions upstream and downstream of WWTP effluent outfalls. The remaining sites were located at successively greater distances downstream of the Empire WWTP effluent outfall, since this stretch of river is expected to experience the greatest improvement in water quality after the planned upgrade is completed. Samples were collected at monthly intervals during ice-free period, as weather and discharge conditions permitted. This design generate 90 samples. Based upon my past research in urban streams (Ferrington and Crisp 1989, Ferrington 1990) and research in progress in Minnehaha Creek (currently funded by WRS) it was anticipated that 60-65 genera, representing 115-130 species with a variety of tolerances to Phosphorus concentrations, sedimentation, and differing dissolved Oxygen concentrations, would occur in the watershed.

Results to date

Sixty-eight genera and approximately 118 species of Chironomidae were collected across the ten sample sites. Seasonality of emergence was distinct, with a progression from Orthocladiinae dominating emergence in early spring, Tanytarsini in late spring and Tanypodinae/Chironomini species being most common in mid to late summer. Prodiamesinae and Diamesinae were only encountered at sites furthest downstream of each WWTP, and were most numerous early and late in the ice-free period. By contrast, Tanypodinae/Chironomini were only abundant at sites located closest to each WWTP.

One site in the upper portion of the Vermillion River was located approximately on kilometer downstream of a tributary that receives outflow from Rice Lake near Lakeville, MN. Chironomidae emergence at this site was strongly influenced by the tributary and emergence in late spring and early summer was dominated by species that are more common in lentic habitats. This site dried during late summer but was quickly re-colonized by both lentic and lotic species that began emerging within 5 weeks of resumption of stream flow. The resilience of chironomids contrasted strongly with other aquatic insects such as mayflies and caddisflies, which took considerably longer to recolonize and grow to maturity.

Preliminary modeling using PCA and CONOCO has been used to search for clusters of species that most closely reflect declining water quality associated with effluents of the WWTPs. Comparisons with similarly designed studies in urban streams of the Greater Kansas City area show that water quality of the Vermillion river is much higher and there is less modification of the Chironomidae community composition downstream of WWTP effluent outfalls.

Ongoing work

We are continuing to refine our identification of species collected during this study and expect that more than 70 genera and 130 species will ultimately be discovered in the Vermillion River. Future modeling attempts will be done to quantify the extent of distance downstream of effluent outfalls that are impacted. More effort will be directed to resolving the temporal patterns of resilience of chironomids after loss of surface flow.

Summary of findings

(1) The longitudinal and temporal patterns of Chironomidae emergence have been documented for 118 species occurring in 68 genera.

(2) Relative abundances of taxa have been determined and site-specific patterns relative to WWTP effluent outfalls have been quantified.

(3) Preliminary modeling shows that effluents are only having minimal, but distinctly detectable, influence on chironomid community composition.

(4) Chironomid community composition is most strongly modified at sites closest to WWTP effluent outfalls.

(5) Outflow from Rice Lake that forms a tributary to the upper portion of the Vermillion River has a substantial modifying effect, shifting community structure strongly to species characteristic of lentic habitats.

(6) Resilience to loss of surface flow, as measured by recolonization and time to emergence, is very high. Chironomidae that rapidly recolonize and grow to maturity after resumption of surface flow consist of a mixture of both lentic and lotic species.

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List of publications & presentations resulting from this project
None to date.

Description of student training provided by project:
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Degree being sought: Masters of Science

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