Appendix H

Relationship of Fast-Water (Rheophile) Macroinvertebrates with Flow

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INTRODUCTION

The purpose of this section is to review the application of invertebrate flow-ecology relationships developed by Wilding and Poff (2008). Two methods were developed by Wilding and Poff (2008), including a low-flow method (Method 1) that was based on rheophile density in Rocky Mountain streams (Figure 1) and a peak-flow method (Method 2) based on diversity and abundance of macroinvertebrates in Rocky Mountain and Interior Western streams. The latter incorporated multiple literature sources and hence incorporates a wide of range of invertebrate metrics and stream types. Therefore application of Method 2 is not expected to be limited by the range of environments included in the source literature. However, riparian vegetation provides a better basis for assessment of peak flows in the Watershed Flow Evaluation Tool, so will not be using Method 2. This review focused instead on Method 1. We address three questions in this review: (1) Where should Method 1 be applied? (2) Which time of year can be evaluated using Method 1? and (3) Which flow value(s) should be used to delineate risk classes?

APPLICATION OF METHOD 1

Where should Method 1 be applied? The method was based on a study by McCarthy (2008) who sampled tributaries to the Fraser River, which are headwater streams of the Colorado River. The Fraser River is in the South Rocky Mountains Ecoregion (Omernik 1987), as are all headwaters of the Yampa, White and Colorado Rivers. The U.S. E.P.A. (Stoddard et al. 2005) and the Colorado Department of Public Health and the Environment (Beyea and Theel 2007) place all headwaters in this ecoregion in the same class of streams, since they are all expected to contain similar biota and respond similarly to disturbance. Likewise, Method 1 can be expected to characterize invertebrate response to flow reductions in headwaters throughout the ecoregion, provided that it is applied at elevations and in hydrogeomorphic settings similar to those sampled by McCarthy.

Subalpine streams were evaluated by McCarthy (2008) and these streams were often shaded by forest. Most sites were within an elevation range of 8,700-9,700 ft, the exception being the Current Creek (Berthoud Pass) where sites ranged from 11,000-11,350 ft (on the treeline demarcating alpine environs). The Method 1 relationships may not hold true for lower elevation sites where temperatures are warmer and there is less shade. For example, elevated temperatures in summer could increase stress and magnify effects of reduced flow. Lower elevations could also experience reduced temperatures in winter as a result of a shallow or absent snowpack, increasing the risk of freezing. Limiting the application of Method 1 to sub-alpine nodes between 8,300 and 11,000 ft is expected to improve the relevance of results. This distribution also corresponds well with riparian Subalpine fir - Engelmann spruce distributions (Carsey et al. 2003). This vegetation class provides an indicator of the bioclimatic environment in which the invertebrate response is expected to hold.

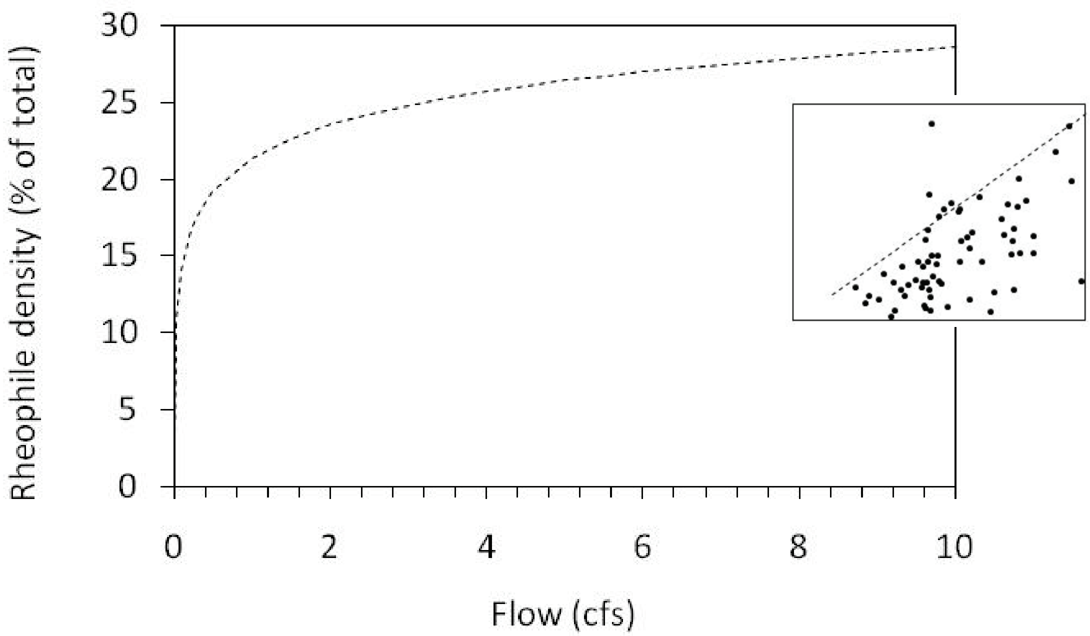

Figure 1 Method 1 reproduced from Wilding and Poff (2008), describing the response of fast-water invertebrates (rheophile species) to the magnitude of flows at the time of sampling. Data are from McCarthy (2008), which focused on a uniform group of small subalpine streams in the Fraser River basin. The upper bound for the data is represented as a 90% quantile ($Y = 7.24 * Log_{10}X + 21.4$; $p = 0.001$). The inset plot shows the data points with the same quantile line on transformed x-axis.

McCarthy (2008) stated results held at "severely diverted sites illustrate consistent losses of habitat, regardless of channel geomorphology". Nonetheless, we decided to be more precise in where this method should be applied by determining the geomorphic settings according to the classification developed by Bledsoe and Carlson (2010) (Table 1). Both high gradient and moderate gradient settings were sampled[1]. Invertebrate response to flow was similar across geomorphic settings (Figure 2). Several geomorphic settings in the study area were not represented in McCarthy's sampling (e.g., glacial troughs) and Method 1 should not be applied to those settings. Rather, it should be applied only to those settings sampled: MEU-moderate energy unconfined, MEC-moderate energy confined and HEC-high energy confined.

Stream size is likely another important factor that should be used to constrain where Method 1 is applied. Using equations from Vogel et al. (1999), we estimated mean annual flow at all sites sampled by McCarthy and determined that the maximum was approximately 8 cfs. Allowing from some uncertainty in the estimate of mean annual flow, we recommend that Method 1 be applied only in streams with mean annual flow <10 cfs.

Table 1 Geomorphic classification of Colorado streams from Bledsoe and Carlson (2010).

Valley Class Name	Energy / Valley Gradient	Valley Bottom Width / Coupling / Confinement	Hillslope Gradient	Energy Potential
Headwaters	> 4%	< (2 L_D + W_{BF})	Both > 30%	High
High-energy Coupled	> 4%	< (2 L_D + W_{BF}) or < (L_D + W_{BF})	Both or at least one > 30%	High
High-energy Open	> 4%	> (2 L_D + W_{BF})	Both or at least one > 30%	High
Moderate-energy Confined	0.1-4%	< 7 W_{BF}	Variable	Moderate
Moderate-energy Unconfined	0.1-4%	> 7 W_{BF}	Variable	Moderate
Canyon	Variable	> 3 W_{BF}	> 70%	Moderate to High
Gorge	Variable	< 3 W_{BF}	> 70%	Moderate to High
Glacial Trough**	< 4%	> (2 L_D + W_{BF})	~ 10-% initially steepening to > 30%	Moderate to Low
Low-energy Floodplain	< 0.1%	> 7 W_{BF}	Generally < 30%	Low

L_D – length of debris runout W_{BF} - width of channel at bankfull stage

** Defined as valleys with the given characteristics, lying above the elevation of the most recent glacial activity

[1] Of the 67 invertebrate samples, 31 were from MEU (moderate energy unconfined), 5 from MEC (moderate energy confined), 27 from HEC (high energy confined) and the 4 high elevation sites were not classified.

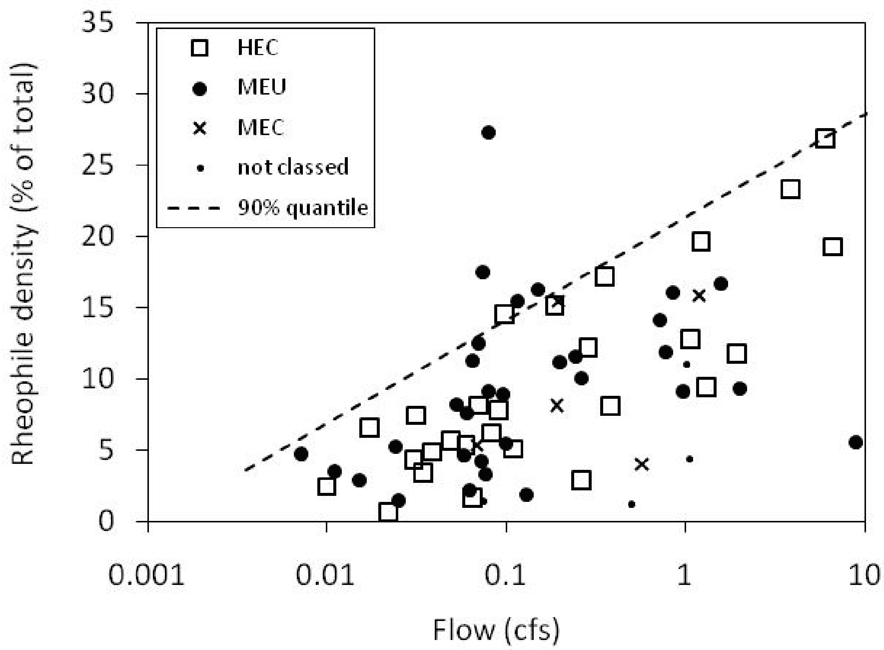

Figure 2 The data points used for Method 1 (note log x-axis) are distinguished based on geomorphic setting (HEC - high energy coupled, MEU- moderate energy unconfined, MEC moderate energy confined). The 90% quantile from Method 1 (all samples) is reproduced on this plot.

Which time of year can be evaluated using Method 1? Anchor ice and changes in flow dependence of invertebrates between fall and winter could diminish the relevance of Method 1 after October. Insect biomass reaches a minimum during the late-spring/early-summer period (Hynes 1970) following emergence of many species. As a consequence, the invertebrate community is likely to differ between spring and summer/fall. Method 1 is therefore recommended for application from July through October, the period during which McCarthy (2008) sampled.

Which flow value(s) should be used to delineate risk classes? For these small, subalpine streams, at any flow value below 10 cfs a further decrease in flow is expected to decrease invertebrate density. At flows less than about 2 cfs, the rate of decrease increases rapidly (Figure 1). There is considerable uncertainty around modeled estimates of such small flows using StateMod, particularly at a daily time step. Using a period of time longer than a day reduces this uncertainty. Instead of the instantaneous measurements used for Method 1 in Wilding and Poff (2008), we now recommended using a 30-day-minimum flow for the period July 1 to October 30. Many streams in the class being considered herein naturally approach flows of about 5 cfs by October. Reductions below 5 cfs caused by stream diversion are expected to distinguish low-risk from an elevated-risk of changes in invertebrate community composition.

Conclusions

Application of Method 1 is recommended for StateMod nodes where mean annual flows are less than 10 cfs (estimated using Vogel et al. 1999). The method was developed using high-elevation streams, and is recommended for application to sub-alpine areas (8,300-11,000 feet). Within this elevation range, the geomorphic setting should be constrained to moderate and high gradient streams (specifically classes MEU, MEC and HEC). Method 1 should be used to evaluate minimum flows from July through October, in contrast to the annual minimum recommended by Wilding & Poff (2008). For risk-class mapping, a flow threshold of 5 cfs—where it differs baseline—is recommended to distinguish low-risk from elevated-risk of changes in invertebrate community composition (measured as a 30-day minimum between July 1 and October 30).

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