Evaluating the "Representative Reach" Component of Rapid Bioassessment Protocol: Variation Among Candidate Stream Reaches

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ABSTRACT
Rapid Bioassessment Protocol (RBP) is a set of guidelines developed by the USEPA to standardize the practice of using qualitative survey techniques on aquatic organisms to gauge stream health. One component of RBP involves selecting a small section of a stream, known as a “representative reach,” which is supposed to represent the conditions found over a larger area of the stream. This study was conducted to examine the variability between reaches in close proximity to each other, and to determine if that variability could be great enough to influence RBP results. I also looked at whether anthropogenic disturbance within the streams watershed appeared to be related to variability between reaches.

Four candidate “representative reaches” were sampled in each of three separate Michigan streams with varying anthropogenic disturbance. Differences among reaches were then evaluated using three common indices: The number of Ephemeroptera, Plecoptera, Trichoptera (#EPT), the Sequential Comparison Index (SCI), and the Michigan Dept. of Environmental Quality “Procedure-51” biotic index. Results indicate little variability between reaches in streams with little impact, and much greater variability between reaches in streams impacted by development. This suggests that monitoring programs for impacted streams may need to sample more reaches to describe conditions compared to streams with little impact.

Introduction
The use of aquatic organisms as indicators of stream impairment and pollution is known as “bioassessment.” One commonly used form of this practice is known as “Rapid Bioassessment Protocol” (RBP) (Plafkin et al., 1989), which is a set of guidelines developed by the United States Environmental Protection Agency intended to standardize the practice of rapid bioassessment. Rapid bioassessment differs from regular bioassessment in that it is a qualitative assessment involving a less intense collection effort than standard quantitative bioassessments. A qualitative assessment approach is intended to reduce sampling time and cost to allow for more streams to be regularly monitored. Use of this protocol or variants of it has become widespread, with half of all U.S. states utilizing some form of RBP (Resh et al. 1995).

One component of RBP typically involves selecting a 300-foot section of a stream or river, known as a “representative reach,” that is supposed to represent the average conditions present over a larger area of the stream. When evaluating an entire stream system, several reaches between headwaters and mouth would likely be surveyed in order to characterize the aquatic community. Often the watershed will be divided into large zones based on land usage or major changes in geology or physical characteristics, or a combination of all three. Samples would then be taken from a representative reach within each zone, and data from all zones combined into the watershed evaluation. In other types of assessments, a single representative reach is used to assess the entire stream. This is often the case with local environmental groups who rely on volunteers for labor, and who try to survey as many streams as possible.

In my study, variability among several “candidate reaches” within similar zones in three separate streams with
Comparing Grand Rapids, Kent Index

ontagon County, MI), = excellent. The

selected within close proximity to one

another? 2.) Do different levels of

anthropogenic disturbance within a

watershed appear to be related to

variation between reaches? 3.) And most

importantly, if variation does exist, is it
great enough to influence management
decisions made based on RBP results?

Methodology

Three separate streams were chosen

based on their degree of anthropogenic
disturbance. One was located within the

Porcupine Mountains State Park

(undeveloped), (lower Little Carp River,

Gogebic & Ontonagon County, MI),

another within a newly developing

suburban area (suburban), (lower Rogue

River, Kent County, MI), and the third

within a heavily urbanized large city

(urbanized), (lower Plaster Creek, Cities

of Wyoming & Grand Rapids, Kent

County, MI). Within each stream system

four different riffles were sampled along a

section approximately four miles in

length, starting from the mouth. All

streams were wadeable 3rd or 4th order.

Riffles were visually surveyed prior to

sampling to ensure that they were located

within a representative reach, following

the guidelines from Plafkin et al., (1989),

and that they were similar in size.

After selecting a riffle, it was

sketched on paper and divided into six

large squares representing equal area

within each riffle. A die was used to

randomly choose locations for five

replicate samples within the riffle (the

number rolled represented which square
to take one sample from. This was

repeated five times; if the same square

was selected more than once, a different

location within that square was used for

successive samples). A standard D-net

and a three-pronged garden claw were

used to disturb an area upstream from

the net within arms reach (approx. one

square meter).

The contents of the net were rinsed

into a three gallon bucket, and the full

capacity of the bucket was used to rinse

the net. Bucket contents were then

poured through a #80 sieve (177

microns), rinsed into a white dissection

pan, and poured into sample bottles.

Samples were preserved in the field with

70% ethanol. Differences between

candidate reaches were evaluated using

the Sequential Comparison Index (SCI),

the "Procedure 51" water quality index

used by the Michigan Department of

Environmental Quality, and the Number

of Ephemeroptera, Plecoptera, and

Trichoptera (#EPT). The SCI scores

streams on the following scale: 0.0 to 0.29

= poor, 0.3 to 0.59 = fair, 0.6 to 0.89 =
good, 0.9 to 1.0 = excellent. Michigan’s

Procedure-51 scores streams on a scale of

0 to >48, with 0 to 18 = poor, 19 to 33 =

fair, 34 to 48 = good, >48 = excellent. The

#EPT is a semi-quantitative measure of
density between orders Ephemeroptera,
Plecoptera, and Trichoptera.

Results

The Sequential Comparison Index

The Sequential Comparison Index is a

measure of diversity within a sample.

The greater the diversity is in a sample,

the higher the score. Large differences in

scores between the sites sampled indicate

a change in community structure. Results

from the SCI showed the most variation

within the urbanized stream (Figure 1).

The greatest contrast was seen between

the first and last sites sampled. Site-A

produced a score of 0.29, while site-D

scored 0.74, a difference of 0.45. This

would equate to site-A being rated

“poor”, and site-D being rated “good”.

A general trend of improved water

quality was seen moving upstream (from

A to D). Site-A and site-B were within

200m of one another yet site-B scored

slightly higher with 0.58, a difference of

0.29. The suburban stream yielded

results with less variation in reaches

assessed than the urbanized stream

(Figure 1). Sites A and B were again

within 200m of one another, yet they

scored 0.74 and 0.79, respectively, a

difference of only 0.05. The greatest

contrast between reaches assessed was

seen between site-B and C, with site-B at

0.79 and site-C at 0.71, a difference of

only 0.08. The undeveloped stream

produced results similar to the suburban

stream (Figure 1). Again, Sites A and B

were within 200m of one another and

scored 0.75 and 0.78, respectively, a

difference of only 0.03. The greatest

contrast was between site-C at 0.82 and

site-D at 0.72, a difference of only 0.10.

Michigan DEQ Procedure-51

The MIDEQ Procedure-51 is similar to

the SCI in that it is a measure of diversity,

however it uses “tolerance scores” rather

than strict mathematical calculations of
diversity. All aquatic organisms are adapted
to tolerate a certain range of environmen­
tal conditions. This range is well known

for most aquatic insect families. Certain

families are more sensitive to changes in

water quality, while others are tolerant to

a wide range of conditions. Different

families are assigned different “tolerance

values” based on their sensitivity. After

identifying and scoring families from a

site, tolerance values are added together
to give the site an overall score.

Higher scores indicate the presence

of sensitive species, which in turn reflects

better water quality. Lower scores

indicate fewer sensitive species, reflecting

poor water quality. Results from this

index were similar to the SCI index

when comparing streams, however it

produced slightly different results from

site to site within a stream. Within the

urbanized stream, the trend of improving

water quality moving upstream (from A
to D) was not as evident as with the SCI
index. Overall, the greatest variation

between reaches assessed was again seen

in the urbanized stream (Figure 2). The
largest contrast between sites occurred with site-B and site-C. Site-B produced a score of 10.1 and site-C produced a score of 35.4. This would equate to site-B earning a rating of "poor", and site-C earning a "good" rating. The suburban stream had the most similarity between sites, earning a rating of "excellent" at all sites. Variation was never more than 3.0 different. The undeveloped stream had the most variability between site-C at 30.8 and site-D at 40.4, a difference of 9.6. The first three sites surveyed earned a "fair" rating, while the last earned a "good" rating.

Number of Ephemeroptera, Plecoptera and Trichoptera, Order-level ID.
The #EPT is a semi-quantitative measure of density among three orders of aquatic insects known to be sensitive to changes in water quality. Sites with higher densities reflect better water quality than those with lower densities. Once again, results from #EPT showed the most significant variation in community structure in the urbanized stream (Figure 3). Sites A and B produced very few individuals, while site C showed an increase only in Trichoptera.

Site D had increased numbers of both Ephemeroptera and Trichoptera. No Plecoptera were present at any of the survey sites. The general trend of increasing diversity moving upstream (from A to D) that was evident with the SCI index is also reflected by this index. Both the suburban (Figure 4) and undeveloped stream (Figure 5) had individuals from all three orders present, with Ephemeroptera having the largest number of individuals at all sites. The suburban stream (Figure 4) was the most consistent between sites, with Ephemeroptera being the most numerous, followed by Trichoptera and Plecoptera. Overall densities were higher in the suburban stream.

Discussion
Because the use of Rapid Bioassessment Protocol (RBP) is so widespread, it is important to be aware of any variability that could influence a stream assessment. This study highlights the importance of site selection as well as the importance in choosing the correct number of sites needed to assess stream conditions. These data also provide a real-life example of variability, i.e. the results from the urbanized stream. The overall results would vary considerably depending on which reach was selected for benthic invertebrate sampling. In order to properly characterize this type of stream, several samples would need to be taken. In the pristine and the suburban stream, in contrast, large differences in community structure were not measured. In those cases, it appears that fewer samples would be needed to characterize those sections of streams.

Combining this information with knowledge of what causes the variation could provide those working in the field with a way to estimate the number of sampling sites needed when establishing water monitoring programs. The distribution of aquatic organisms is known to be dependant on several factors, including the chemical characteristics of the water, habitat availability as well as physical factors such as discharge and substrate type (Merritt et al., 1996). Variation in community structure between reaches throughout an entire watershed can be expected as many of these factors change naturally (Hauer et al., 1996). However within the short sections of streams that were surveyed in this study it is doubtful that natural variation would be detected using qualitative sampling methods. Past research has indicated minimal variation between reaches in streams with minimal impact (Rabeni et al., 1999).

As anthropogenic disturbance to a stream increases, the likelihood that natural variation would give way to unnatural variation increases. It was expected that this variation would become evident with qualitative survey techniques. My data supports this hypothesis. The urbanized stream was impacted in many ways, and is subjected to several types of pollutants, including wastewater discharges from sewage treatment plants and storm water runoff from roads and parking lots.

Because of the age of development within this portion of the streams watershed, there were no modern storm water retention basins of any kind. It also lacks a sufficient riparian buffer in many areas. Development is still underway in the middle reaches of the streams length, resulting in further destruction of the buffer. All of these factors contribute to poor water quality, and this is reflected by the data. The results from the Sequential Comparison Index (Figure 1) clearly show more variation in the urbanized stream than in the suburban and undeveloped streams. The Michigan Procedure-51 index (Figure 2) and the #EPT (Figures 3, 4 & 5) also show more variation from site to site in the urbanized stream. Variation within the suburban stream was less than the urbanized stream. The development within the portion sampled is newer than that found within the urbanized stream and is not nearly as dense.

New regulations related to land development and storm water runoff which did not exist during development of the urbanized stream have been implemented to protect the waterway. Storm water retention basins are common, and a very good riparian zone is present in most places. Site to site variation within the undeveloped stream was similar to the suburban stream, again suggesting smart development within the suburban stream's watershed maintains water quality. The data from the undeveloped and suburban stream demonstrates that in the absence of any serious impairment, consistent
community structure is maintained; site to site variation is minimal.

The differences in densities shown with the #EPT index between the undeveloped and suburban stream are due to differences in stream size, with the suburban stream being larger than the undeveloped stream. This provides greater habitat and nutrient availability which increases productivity throughout the stream, resulting in higher densities. A notable result of this study shows that impacted streams with heavy, uncontrolled or older development have greater site to site variability than un-impacted streams. Even though a stream may be located in a developing area, if the development is controlled and planned it will not significantly impact the water quality. By combining knowledge of benthic invertebrate community structure with knowledge of the many ways in which a waterway can be impaired, one can predict the state of the community in a given stream. This provides a researcher with a way to estimate the number of samples that would be required to properly characterize a given stream.

**Recommendations**

Rapid bioassessments (RBPs) are intended to allow for monitoring water quality on as many streams as possible at a minimal cost (Lenat *et al.*, 1994). Any knowledge related to their effectiveness therefore becomes extremely valuable when making decisions on where to use them and to what extent. The results of this study indicate that variability between reaches in close proximity to one another is related to the degree of disturbance to the stream. Essentially this means that large-scale monitoring programs could exert less effort on assessing streams with fewer disturbances. In contrast to this, heavily developed streams with the possibility of significant variation between reaches might require a more intense survey to locate problem areas. This information could be used as guidance when monitoring programs are established. In addition, it is important to consider the type and age of development within a watershed when planning an RBP program. Although a section of a stream may have development within it, if it is done correctly it will preserve water quality. This would allow for a minimal number of reaches to be sampled. Also, further studies on a watershed-wide basis rather than a short portion of the stream could be conducted to aid in estimating sampling intensity requirements in various watersheds.
Figure 1. SCI Scores for urbanized, suburban, and undeveloped streams.

Figure 2. Procedure-51 Scores for the urbanized, suburban, and undeveloped streams.
Figure 3. Approximate densities of Ephemeroptera, Plecoptera, and Trichoptera (#EPT) for the urbanized stream (# / m²).

Figure 4. Approximate densities of Ephemeroptera, Plecoptera, and Trichoptera (#EPT) for the suburban stream (# / m²).
Figure 5. Approximate densities of Ephemeroptera, Plecoptera, and Trichoptera (#EPT) for the undeveloped stream (# / m²).

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