

Standard Operating Procedure #12:

Data Analysis

Version 1.0

In Monitoring Protocol for Wadeable Streams of the Great Lakes Network

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this standard operating procedure will promptly notify the project manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The project manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to Procedure for Revising the Protocol, SOP #16.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

Acknowledgements

We relied on Barbour et al. (1999) and Lillie et al. (2003) in our discussion of multimetric indices. Special thanks to J. Ramstack for assistance with understanding multivariate ordination methods.

12.0 Introduction and Background

This standard operating procedure (SOP) contains information on types of data analysis that may be used for annual data summaries and to determine trends in wadeable streams. A variety of statistical techniques and indices are discussed, however, only a subset is likely to be used at any one time or to address any single monitoring objective. Additionally, as advances in analytical techniques arise, we will consider their appropriate use for GLKN wadeable stream data.

The data collected on wadeable streams includes continuously-logged data (i.e., temperature and depth), synoptic data that is both categorical (e.g., substrate type) and continuous (e.g., core water quality), and biological community assemblage data (i.e., macroinvertebrates and periphyton), each of which requires a different method of analysis.

The appropriate analysis technique will be selected to address each of the following monitoring objectives:

- Monitor stream stage and flow to determine annual and seasonal means, flashiness, and timing and duration of peak flow. Analyze for change over time.
- Monitor water temperature to determine diurnal, seasonal, and annual variability; annual and seasonal means; timing and duration of maximum temperatures. Analyze data for change over time. Summarize data relative to current stream designations (e.g., cold water fishery).
- Monitor macroinvertebrates, periphyton, and habitat characteristics to assess current stream conditions and analyze for change over time. Relate the invertebrate and algae communities to overall water quality through use of indices as indicators of water quality and habitat condition.
- Relate observed changes in flow, chemistry, biology, and habitat to surrounding land use, climate, and air quality data acquired from other sources.

12.1 Analytical Methods

Analysis of both the status and trends of streams will be conducted. Status refers to a static description of a stream at a point in time. Trend refers to directional change over a period of time. Common analytical methods for assessing status and determining whether a trend is occurring are discussed below. In addition, if long-term trends indicate change may be occurring, methods are included for identifying the minimum level of change that is detectable with statistical significance.

12.1.1 Status

1. Temporal plots. Graphs of streams data as a function of time provide a quick assessment of status. For designated uses of stream resources, a regulatory water quality limit or standard can be overlain on temporal plots to identify the temporal pattern of exceedances. The annual percent exceedance of the standard (percent of the year that the stream exceeds the standard) can be calculated from the data.
2. Normal data methods. The summary statistics used for the analysis of normally-distributed data will be medians, means, and standard deviations. Medians are useful for an assessment of the central tendency of stream data, while means are sensitive to extreme values and will reflect the influence of climate events (storms and drought) on the data; the mean value will be sensitive to the magnitude and frequency of events. Standard deviation is a common measure of variability and is necessary for the assessment of detectable change. Summary statistics like monthly medians are discrete data rather than continuous data, and temporal plots of summary statistics should be bar charts.
3. Non-normal data transformations. The standard formulas for calculating summary statistics assume a normal distribution to the data, which is not always the case for environmental data. Statistical frequency curves or histograms of the data will show whether highly skewed data should be transformed. Right-skewed data ($\text{mean} \gg \text{median}$) can be transformed toward a normal distribution using square-roots or $\log_{10}$, while left-skewed data ($\text{mean} \ll \text{median}$) can be transformed using exponents (McCune and Grace 2002). Normal data methods are then conducted on the transformed data. Summary statistics derived from transformed data must then be reverse-transformed for comparison plots and reporting.
4. Nonparametric methods. If, after the above data transformations are performed and the data distribution is still far from normal, then nonparametric approaches may be necessary. Differences between independent samples can be assessed with the Wald-Wolfowitz runs test, the Mann-Whitney U test, and the Kolmogorov-Smirnov two-sample test. For multiple independent samples, one uses the Kruskal-Wallis analysis of ranks and the Median test. Differences between dependent samples can be assessed with the Sign test and Wilcoxon's matched pairs test. Nonparametric correlation coefficients, either Spearman R, Kendall Tau, or Gamma coefficient, can be used to express relationships between two variables.
5. O/E analysis methods. The status of wadeable stream variables can be evaluated by comparing the observed conditions with the unimpacted state of a given stream, i.e., the best-

available information for the expected conditions that would occur in the absence of human-induced ecological stress. For streams with a long monitoring history, the expected condition might be discerned from monitoring data collected prior to major land use changes. For streams without a long monitoring history, the expected condition can be estimated from a regional population of reference streams. In most cases, truly pristine conditions are unlikely to be found, so the 'reference stream' population is derived from those that are least-disturbed or impacted by human interference. For GLKN, this would require the development of a Western Great Lakes Region reference stream dataset, which would include streams that had been monitored for the variables in this protocol. A starting point for this endeavor might be the reference streams used for the national Wadeable Streams Assessment (WSA) conducted by the EPA (USEPA 2006) or data collected by state agencies. The extent of the Upper Midwest ecoregion used for the EPA study correlates well with GLKN boundaries; the WSA identified twelve reference streams for this ecoregion (www.epa.gov/owow/streamsurvey/web_data.html). Once the expected condition (E) has been determined and the observed condition (O) has been measured, an assessment of the normalized ratio (O/E) enables comparisons between parks and park networks.

6. Multimetric versus multivariate methods. Reynoldson et al. (1997) compared the performance characteristics of selected multivariate methods with selected multimetric index methods. They concluded that multivariate approaches had higher precision and accuracy than the multimetric approaches. In contrast, Fore et al. (1996) found that a multimetric index performed better than a principal components analysis in detecting impacts of disturbance on Oregon streams. A combination of multimetric index and multivariate approaches will be used for the analysis of periphyton and macroinvertebrate data; each approach is discussed in the following sections (8 and 9). The pros and cons of the two approaches are compared in Table 1 and summarized as follows. Generally, the status of monitored stream sites is usually determined by comparison to unimpaired conditions, either in the form of a single pairing to a nearby site (e.g., upstream versus downstream) or by comparing the monitored site with the average condition observed at groups of reference sites. Reference sites are selected using best professional knowledge of the location of unimpaired sites, then grouped using a classification system (Table 1). In the multimetric index approach, the classification system is usually chosen *a priori*, based on similar physical, chemical, and/or geographical attributes of the reference sites; a common example is the ecoregion framework of Omernik (1995). In the multivariate approach, the classification system is chosen *a posteriori*, based on the maximum possible distance (in variate space) between groups of sites. The physical or chemical environmental variables that best distinguish the groups from each other are chosen based on the variance of the data, no matter if the sites in each group are located in the same ecoregion. Therefore, multivariate methods usually require a larger database of reference sites to develop a predictive model (Norris 1995). Two highly-developed multivariate models, RIVPACS and its derivative AusRivAS, can be tailored to a geographical region for the most accurate predictions of community assemblages for the season and habitat sampled. However, to date, these models are untested for multihabitat sampling techniques (Norris 1995) that have been chosen for the GLKN wadeable streams protocol.

Table 1. Comparison of some aspects of multimetric and multivariate data analysis methods.

	Multimetric Analysis	Multivariate Analysis
Classification of Reference Sites	<i>A priori</i> : Ref. sites clustered by environmental variables or geography (i.e., ecoregion, land use, ...)	<i>A posteriori</i> : Ref. sites clustered according to environmental variables in variate space, independent of geography
Assumptions	Biota are similar within a given class (i.e., geographic area)	Biota are similar when environmental variables are similar
Advantages	Quicker development time	• Once model developed, quick output includes expected biota • Can be tailored to region
Disadvantages	Metrics need testing due to variability within and between regions	• Slower development time • Requires larger database of reference sites • Untested for multihabitat method

7. Multimetric index methods. The overall sequence of steps to calculate a multimetric index is to collect samples from reference sites and monitoring sites, identify and enumerate taxa for individual metrics, determine the reference condition for each metric, select classification criteria and calculate individual scores, calculate composite score, generate the overall classification scheme and determine final assessment. Table 2 contains examples of multimetric indices that have been used for macroinvertebrates in the Western Great Lakes region. Multimetric indices for periphyton are listed in Table 4. Any of these indices are potentially useful for GLKN wadeable streams. Whichever index is evaluated and selected, it should be tested to verify that the index shows a response to the type and range of human perturbations in these particular streams. The index data for reference sites and monitoring sites can be compared in side-by-side box plots.
8. Multivariate ordination methods. Ordinations are multivariate methods commonly used for analysis of community assemblages. The techniques analyze the data in multidimensional space and report the results in a two-dimensional graph, with sites that have similar species assemblages closer to each other than sites with different assemblages. Environmental data from each site is then used for interpretation of the axes and to explain the groupings of sites in the resulting graph.

Ordinations are used to explore and understand how species abundance relates to environmental variables (McCune and Grace 2002, Gauch 1982). From McCune and Grace (2002):

Ordination often helps to:

- *select the most important factors from multiple factors imagined or hypothesized*
- *separate strong, important patterns from weak ones, and*

- *reveal unforeseen patterns and suggest unforeseen processes.*

Multiple ordination methods are available for use in community ecology, such as principal components analysis, detrended correspondence analysis, canonical correspondence analysis, nonmetric multidimensional scaling, reciprocal averaging, and others. We will evaluate and use the methods that are most applicable to the wadeable streams data.

Table 2. Summary of potential multimetric indices that are used for macroinvertebrates in the western Great Lakes region, including their expected response to increasing human perturbations.

Agency (Source) Indices	Notes	Expected Response to Increasing Perturbations
EPA (USEPA 2006)		
Macroinvertebrate Index of Biotic Condition	Metrics in six categories selected for each ecoregion	Increase
WDNR (Lillie et al. 2003)		
Hilsenhoff Biotic Index (HBI)	Not sensitive to inorganic pollution	Increase
Family Biotic Index	Rapid screening tool	Increase
True HBI	Not well-correlated to water quality	Increase
Percent Ephemeroptera-Plecoptera-Trichoptera (%EPT)	Rapid screening tool	Decrease
Max-x HBI	Balance between HBI & MTV	Increase
Margolef's Diversity Index	Sensitive to metals, easy to use	Decrease
B Similarity Index	Sensitive to rare taxa	Decrease
Standers' Similarity Index	Sensitive to dominant taxa	Decrease
Ecological Distance (dissimilarity index)	Combines richness & abund.	Increase
Percent Similarity	Sensitive to sample size	Decrease
Coefficient of Community Loss	Range is unlimited	Decrease
MPCA (Genet and Chirhart 2004)		
Macroinvertebrate Index of Biotic Integrity	Indices for three habitat classes, 7-10 metrics each	Decrease
MIDEQ (Creal et al. 1996)		
Procedure 51	Nine metrics	Increase

Trends

1. Mann-Kendall method. This method is appropriate for a step-wise trend comparison of wadeable streams data collected on an annual basis. The Mann Kendall test computes Kendall's tau nonparametric correlation coefficient and its test of significance (Helsel and Hirsch 2002) for any pair of X and Y data. If X is time, the test is for trend in the Y variable.

2. Seasonal Kendall method. This method is appropriate for an assessment of the wadeable streams data collected continuously throughout the monitoring season (i.e., logger data). The Seasonal Kendall test performs the Mann-Kendall trend test for individual seasons of the year, where season is defined by the user. It combines the individual results into one overall test for whether the dependent (Y) variable changes in a consistent direction (monotonic trend) over time.
3. Regional Kendall method. The Regional Kendall test extends the concept to spatial locations rather than seasons. A Mann-Kendall test is computed for individual locations and results are combined into one overall test for consistent regional trend. The test is applicable to data where observations have been made annually at numerous locations, and one overall test is desired to determine whether the same trend is evident across those locations.

Detectable Change

1. Power analysis methods. The ability to detect statistically-significant change in parametric (normally-distributed) data is determined using statistical power analysis. Statistical power analysis requires an understanding of five key parameter values: mean, variance, alpha, beta, and sample size. Mean and variance are calculated from the observed data, while alpha and beta are selected as the acceptable levels of uncertainty (Type I and Type II errors), typically 5% and 20%, respectively. When conducting power analysis on a single site, the sample size (n) represents the size of the monitoring record. Power analysis is especially dependent upon variability in the data. However, as sample size increases, the variance of the data tends to decrease. As the monitoring record grows, an assessment of between-year variability of the annual means will be possible. Once this information is developed, the change that is detectable from the dataset above this degree of variability can be determined. The minimum detectable change represents the smallest difference or change that would be statistically significant.
2. Two-sample tests. Two-sample tests for non-parametric data (step trend sensu Helsel and Hirsch 2002) such as the t-test and Wilcoxon rank-sum test may be used to detect statistically significant changes between any two sampling periods.

12.2 Continuously-logged Data: Depth, Temperature, and Water Quality

A continuous temperature/depth (pressure) logger will be installed in each sampling reach. With enough stage-discharge measurements conducted over time, flow depth data can be converted to flow discharge data; summary statistic methods will not differ for either unit of measure (ft. or cu-ft. /sec).

1. Continuously logged data will be scrutinized for drift or other signs of problems with the data; any identifiable drift will be corrected for by using an appropriate software package (e.g., Aquarius). Missing data due to equipment failure will not be interpolated, but data from a back-up instrument or from a field visit may be used as surrogate data where appropriate.
2. Continuously recorded data should be evaluated with daily, monthly, seasonal (specify time periods, e.g., March–May, June–September), and annual summary statistics (median, mean, and standard deviation).
3. As the monitoring record grows longer, the daily mean values for a given year can be compared with daily medians for the entire monitoring record.
4. The status of stream depth or flow will be evaluated from the digital logger data using the following measures:
 - Runoff events: number and timing (dates) for each monitoring period
 - Temporal plot indicating peak flow period: duration and annual timing of seasonal runoff above annual baseflow.
 - After hydrograph separation of data, proportions of annual flow that occur as stormflow and baseflow.
 - Convert monthly mean flow volumes to proportion (%) of mean annual flow.
5. Variability in the cumulative flow record can be evaluated by plotting:
 - monthly mean $\pm$ 1SD,
 - difference of annual means from a long-term mean,
 - mean annual flows fit with a linear trend line,
 - comparison of the monthly mean flows of different monitoring periods (e.g., June 2011 vs. June 2013, or Jun–Sep 2010–2014 vs. Jun–Sep 2015–2019), or
 - moving average of the entire record.
6. Assess the effect of climate change using hydrograph separation. Hydrograph separation identifies the major components of flow in wadeable streams: stormflow, the short-term

runoff response of the stream's watershed, and long-term baseflow, sustained by groundwater discharge from the subsurface (either interflow or spring flow). Two easily accessible means of hydrograph separation are: the USGS software HYSEP (Sloto and Crouse 1996), and the Web-based Hydrograph Analysis Tool (WHAT) offered by the Agricultural and Biological Engineering Department at Purdue University (<http://cobweb.ecn.purdue.edu/~what/>).

7. Seasonal Kendall trend tests. After three years of monitoring data have been compiled, and thereafter, seasonal Kendall trend tests can be conducted on the monthly and annual medians calculated for each year's data. To evaluate the effects of climate change, additional trend tests could be useful: the trend in onset and duration of peak flow, and the trend in stormflow proportions or the baseflow index (BFI) as determined by annual hydrograph separation.

12.3 Synoptic Data: Habitat and Water Quality

During the annual sampling visits to GLKN wadeable streams, the core water quality suite of variables will be measured at each stream. The water quality data will aid in the interpretation of habitat and biological data and will provide information to park managers on the relative condition of the stream.

1. Annual reporting will include these results in cumulative time series plots.
2. Once estimates for all parameters have been obtained for each habitat sample (Table 3), averages, ranges, and a measure of variability among individual samples (standard deviation) and riffles (standard error of the mean) are obtained for each sampling reach.
3. Categories for percentage class intervals are first converted to median values to estimate percent coverage for each variable (*i.e.*, 0 = 0%, 1 = 5%, 2 = 25%, 3 = 57.5%, and 4 = 87.5%). Mean percent for each habitat variable is then calculated for each riffle and reach.
4. During multivariate analyses, summary statistics of habitat and water quality variables will be used in conjunction with periphyton and macroinvertebrate community metrics.

Table 3. Summary of the types of data collected during habitat surveys in wadeable streams.

Habitat Measure	Spatial frequency	Variable type
Bankfull Width	Once per transect	Continuous
Bankfull Depth	Once per transect	Continuous
Wetted Stream Width	Once per transect	Continuous
Average Stream Depth	Four per transect, averaged	Continuous
Maximum Stream Depth	Once per transect	Continuous
Depth of Fines and Water	Four per transect, averaged	Continuous
Embeddedness	Four per transect, averaged	Proportion
Substrate type	Four per transect	Category
Algae	Four per transect, averaged	Quadrat proportion
Macrophytes	Four per transect, averaged	Quadrat proportion
Canopy Cover	Four per transect, averaged	Proportion
Habitat type	Once per transect	Category

12.4 Biological Community Data: Periphyton and Macroinvertebrates

Biological community samples yield population data, or head counts for all taxa that are identified. Once the raw data are obtained, ecological health is determined by the assessment of various metrics that incorporate one individual metric or multimetric indices of the data. Generally, the purpose of the metrics is to characterize streams and identify potential impairments, relative to the

characteristics of a set of reference streams. Those metrics that are most effective are those that demonstrate a response across a range of human influence; these ‘best’ metrics have undergone rigorous testing (discriminatory analysis) and have been evaluated for the ability to distinguish impairment.

Two types of periphyton data will be collected during each monitoring visit: 1) estimates of periphyton coverage of substrate during habitat surveys along eleven transects for each stream site, and 2) a composited multihabitat sample of periphyton, preserved for laboratory identification and analysis at a later date. The composite sample will be analyzed using both multimetric and multivariate (community assemblage) techniques. Table 4 summarizes the periphyton metrics and multimetric indices recommended by Barbour et al. (1999). Some of the metrics and indices generally characterize biotic integrity without specifically diagnosing ecological conditions and causes of impairment, while other metrics and indices more specifically diagnose causes of impaired biotic integrity.

Table 4. Summary of periphyton metrics and indices described in Barbour et al. (1999).

Periphyton Metric/Index	Use or Sensitivity
Species Richness (SR)	General biotic integrity
Genera Richness (GR)	General biotic integrity, possibly more accurate than SR when abundant species are clustered within genera
Total Number of Divisions	Highest for good water quality and good biotic integrity
Shannon Diversity Index (diatoms)	Organic (sewage) pollution
Percent Community Similarity (diatoms)	Useful for comparisons
Pollution Tolerance Index (diatoms)	Similar to Hilsenhoff, depends upon assigned tolerance values
Percent Sensitive (diatoms)	Useful for small streams with low primary productivity
Percent <i>Achnanthes minutissima</i>	Recolonizer, indicating scour or toxic events
Percent live (diatoms)	Low for high sedimentation
Percent Aberrant (diatoms)	Heavy metals
Percent Motile (diatoms)	More abundant under siltation
Simple Diagnostic metrics	Sum of the relative abundance of species diagnostic of potential stressor (i.e., pH, salts, oxidation of organics)
Simple Autecological Indices (SAI)	Assigns ranked categories of known preferences along a stressor gradient
Weighted-Average Indices (WAI)	Uses optimal environmental condition and relative abundance of each taxa (Relative abundances are weighted toward optimal conditions)
Deviation from expected ecological condition (Δ_{EC})	Similar to observed vs. expected methods, based on the expected EC of regional reference sites

Table 5 summarizes the macroinvertebrate metrics described by Barbour et al. (1999) and Lillie et al. (2003); those metrics that are used in the western Great Lakes region or are otherwise recommended have been noted in the table. However, any of the metrics listed in the table should be considered as viable candidates, and all metrics require testing to verify their usefulness for the Western Great Lakes region. Examination of individual metrics or indices can provide clues to the causes of assemblage shifts. For instance, shifts in HBI values could indicate changes in pollutant sources because this metric includes tolerance values for organic pollutants, while a shift in the percent

predators could indicate a shift in the food web resulting from changing land use surrounding a stream. As with periphyton, analysis will consist of both multimetric (see Table 2) and multivariate techniques. The following should be taken into consideration:

1. Lillie et al. (2003) caution against fixed-count sub-sampling, discussing the importance of uniform methods, and suggest that taxa density (number collected per unit area) may be a useful metric to account for diverse habitats and stream sizes.
2. If count data are collected using fixed-width (strip) transects, point counts, quadrat counts or other cluster sampling methods, they will usually follow a Poisson or negative binomial distribution. It has been found that when the mean count increases, as with dominant taxa, the normal distribution can provide a good approximation of count data. However, counts of rare species tend to result in a frequency distribution that is strongly skewed to the left. In addition, the variance of counts is usually related to the mean which violates the assumptions of most parametric tests. Therefore the choice is either to transform the data to resemble a normal distribution, or to analyze the data using methods that model the Poisson or negative binomial as the assumed distributions. Generalized linear models utilize the fact that the negative binomial distribution can fit random or clumped distributions, estimating m and k from a count data set, such that robust inferences can be gained about both the central tendency and dispersion of the data set. Furthermore, pair-wise comparisons between data sets can be made to test hypotheses concerning the difference between population abundance (as reflected by counts) and dispersion of individuals within the populations (based on values of k).
3. Hawkins et al. (2000) used the O/E method to estimate the expected number of macroinvertebrate taxa at stream sites, and the USEPA (2006) used the method to compare sites across and between ecoregions. A good reference data set (expected) is required for this method.
4. Trend in macroinvertebrate assemblage structure can be evaluated after two sampling rotations and thereafter. Once several years of sample data become available, linear trends in measures such as % EPT as a function of time can also be evaluated (Helsel and Hirsch 2002). Simple graphical tools to display biologically important changes in macroinvertebrate indicators over time will also be very powerful.
5. Sandin and Johnson (2000) conducted statistical power analysis of a multimetric index using the coefficients of variance derived from a spatial dataset of 700 stations, and a temporal set from five stations that spanned 6–11 years. In addition to increasing the number of samples, precision can be further increased by stratifying into areas that are likely to have similar abundance and distributions.

Table 5. Summary of macroinvertebrate metrics.

Category	Macroinvertebrate Metrics	Expected Response to Increasing Perturbations
Richness (Population) Measures	# Total taxa (family, genus, species levels) ^{1 2 3}	Decrease
	# EPT ^{1 2}	Decrease
	# Ephemeroptera (mayfly) ^{1 3}	Decrease
	# Plecoptera (stonefly) ^{1 3}	Decrease
	# Pteronarcys species	Decrease
	# Trichoptera (caddisfly) ^{1 3 0}	Decrease
	# Diptera (true fly) ⁰	Decrease
	# Chironomida (midge)	Decrease
	# Ephemeroptera + Plecoptera ⁰	Decrease
	# Odonata + Trichoptera ⁰	Decrease
	# Plecoptera + Odonata + Ephemeroptera + Trichoptera ⁰	Decrease
	# Non-insecta ⁰	Decrease
	# Gastropoda ⁰	Decrease
Composition (Relative Abundance) Measures	% EPT/total ¹	Decrease
	% Ephemeroptera/total ^{1 3 0}	Decrease
	% Caenida/total	Increase
	% Plecoptera/total	Decrease
	% Trichoptera/total ³	Decrease
	% Hydropsychida/Trichoptera	Increase
	% Odonata/total	Increase
	% Diptera/total	Increase
	% Chironomida/total	Increase
	% Tanytarsinid/total	Decrease
	% Coleoptera + Hemiptera ⁰	Increase
	% Non-insecta ⁰	Increase
	% Amphipoda/total	Decrease
	% Isopoda/total ³	Increase
	% Corbicula/total (asiatic clam)	Increase
Tolerance Measures	% Oligochaeta/total ⁰	Varies
	# Intolerant taxa ^{1 0}	Decrease
	# Intolerant mollusca	Decrease
	% Intolerant/total ⁰	Decrease
	% Tolerant/total ^{1 0}	Increase
	% Surface breathers ³	Increase
	% Sediment tolerant	Increase
	% Dominant/total (family, genus, species levels) ^{1 3 0}	Increase
	% Multivoltine/total (>1 lifecycle/yr)	Increase
Feeding Group Measures	% Univoltine/total (≤1 lifecycle/yr)	Decrease
	% Omnivores + Scavengers/total (generalists)	Increase
	% Predators/total	Varies
	% Grazers/total ¹	Decrease
	% Scrapers/total ^{1 0}	Decrease
	% Shredders/total	Decrease
	% Filterers/total ¹	Varies
Habitat Measures	% Collectors/total ⁰	Varies
	% Clingers/total ¹	Decrease
	# Clingers ^{1 0}	Decrease

¹ Recommended by Barbour et al. (1999) as having proven ability to distinguish impairment.

² Shown by Sandin and Johnson (2000) to have high statistical power to detect change.

³ Used by MIDEQ (2008).

⁰ Used by Genet and Chirhart (2004).

12.5 Quality Assurance/Quality Control Procedures

Data quality must be assured at all stages of a monitoring protocol. This section is intended to demonstrate how the data analysis methods generate data of known and documented quality, resulting in complete, accurate, and transferable information. Data credibility necessary for the intended uses will be achieved when the data are:

- consistent over time and consistent among staff members
- collected and analyzed using standardized and acceptable techniques
- comparable to data collected in other assessments using the same methods

When data are credible, they can be used to make management decisions. In particular, quality assurance during the analysis of wadeable streams data is maintained when the assumptions and requirements of statistical methods are met (e.g., normal distribution, sample independence, etc.). For multimetric assessment methods, the precision of the total multimetric score is of interest, as well as the precision of the individual metrics that make up the score (Barbour et al. 1999). Table 6 compares performance characteristics, like precision and bias, of chemical and biological monitoring data.

Table 6. Translation of some performance characteristics, derived for laboratory analytical systems, to biological laboratory systems. Taken from Diamond et al. (1996).

Performance Characteristics	Analytical Chemical Methods	Biological Methods
Precision	Replicate samples	Multiple taxonomists identifying 1 sample; split sample for sorting, identification, enumeration; replicate samples within sites; duplicate reaches
Bias	Matrix-spiked samples; standard reference materials; performance evaluation samples	Taxonomic reference sample; “spiked” organism samples
Performance range	Standard reference materials at various concentrations; evaluation of spiked samples by using different matrices	Efficiency of field sorting procedures under different sample conditions (mud, detritus, sand, low light)
Interferences	Occurrence of chemical reactions involved in procedure; spiked samples; procedural blanks; contamination	Excessive detrital material or mud in sample; difficulty in identification of early life stages; taxonomic uncertainty
Sensitivity	Standards; instrument calibration	Organism-spiked samples; standard level of identification
Accuracy	Performance standards; procedural blanks	Confirmation of identification, percentage of “missed” specimens

12.6 Literature Cited

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