Development of the New Jersey High Gradient Macroinvertebrate Index (HGMI)

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Executive Summary

The New Jersey Department of Environmental Protection (NJDEP) determined that its biological indicator for benthic macroinvertebrates in high gradient wadeable streams was due for evaluation and possible re-development. This report evaluates performance of the existing indicator (the New Jersey Impairment Score) and examines revisions to the indicator that improve its sensitivity to natural variability among sites and its responsiveness to environmental stresses.

The outcome of the evaluations and revisions was the development of a new tool for identifying biological degradation in the high gradient streams of New Jersey: the High Gradient Macroinvertebrate Index (HGMI). Two forms of the index were developed, one for application with genus level taxonomy and one for family level data. For the $HGMI_{gen}$, seven metrics are calculated and scored for inclusion in the index:

- Total number of genera
- Percent of genera that are not insects
- Percent of EPT individuals (excluding Hydropsychidae, including Diplectrona)
- Number of scraper genera
- Hilsenhoff Biotic Index
- Number of attribute 2 genera (highly sensitive and uncommon taxa)
- Number of attribute 3 genera (sensitive and common taxa)

Five metrics are calculated and scored for inclusion in the $HGMI_{fam}$:

- Number of EPT families
- Percent of families that are not insects
- Percent of individuals that are EPT (excluding Hydropsychidae)
- Number of scraper families
- Family Biotic Index

For combined calibration and verification data, all stressed sites had HGMI scores lower than the 25^{th} percentile of reference scores (discrimination efficiency = 100%). The $HGMI_{gen}$ is more precise than the $HGMI_{fam}$ and should be used when taxonomic expertise for reliably identifying genera is available.

The HGMI accounts for natural variability through metric adjustments of those metrics that were correlated with catchment area, the only natural environmental variables that had any significant effect on metrics in reference sites. There is no categorical classification by stream size. Rather, metrics are adjusted on a continuous scale using the regression relationships between metric values and catchment size in reference sites.

We recommend applying the HGMI in high gradient sites where samples are collected between April 1 and November 30 and processed using NJDEP protocols. Metrics must be calculated using taxa identifications at levels appropriate to the indices (genus or family), attributes defined by NJDEP, and metric adjustment and scoring formulae provided in Tables 5 and 6 of this report. HGMI results can be used in bioassessments, provided that the uncertainties associated with thresholds and unaccounted-for natural variability are stated as part of the assessments. Particular natural conditions that have not been adequately tested include very small, very large, and limestone streams.

NJDEP must select an impairment threshold if the HGMI is to be used in bioassessments. Three approaches for threshold selection are suggested. They include:

1. Select a percentile of reference site HGMI scores based on confidence in the reference site selection and the disturbance levels expected in those sites,
2. Balance error between Type 1 and Type 2 error rates, and
3. Use Biological Condition Gradient Tiers to associate HGMI values with descriptions of biological alterations.

Optimally, NJDEP will consider all three approaches to bolster the selection of a threshold of the HGMI to distinguish impaired from unimpaired biological conditions.

Acknowledgements

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Acronyms and Abbreviations

AMNET	Ambient Biological Monitoring Network
BC	Bray-Curtis similarity measure
BCG	Biological Condition Gradient
CV	Coefficient of variability
DE	Discrimination efficiency
DFA	Discriminant function analysis
EPA (U.S. EPA)	United States Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
HGMI	High Gradient Macroinvertebrate Index (at genus and family levels)
NJDEP	New Jersey Department of Environmental Protection
NJIS	New Jersey Impairment Score
NMS	Non-metric multidimensional scaling
r^2	Regression coefficient

Table of Contents

List of Tables

List of Figures

1.0 Introduction

The primary goal of the Clean Water Act is to preserve and protect the biological integrity of the Nation's waters. Stream aquatic resources in New Jersey are threatened by continued degradation caused by numerous unnatural stressors. Biological measures that are indicative of environmental stresses have been used to assess the condition of stream resources. Though these indicators have been effective, they are due for evaluation and re-calibration because additional data have been compiled, allowing refinement of the indicators. In the course of indicator refinement, one specific question that can be examined relates to biotic conditions in headwater streams. Headwater streams may be more vulnerable to human activities than larger wadeable streams because of their small size and relative proximity to stressor sources. Evaluation of the sensitivity of biological indicators to stresses in small watersheds is a secondary reason for evaluating and re-calibrating New Jersey's biotic indicators for streams.

The New Jersey Department of Environmental Protection (NJDEP) routinely monitors waterbodies for various chemical, physical, and biological parameters. Biological monitoring includes sampling for macroinvertebrates and fish. NJDEP has developed macroinvertebrate and fish protocols, which are used together to assess environmental conditions of non-tidal wadeable streams. Through the Ambient Biological Monitoring Network (AMNET), streams have been assessed with benthic macroinvertebrates using a multimetric index, namely the New Jersey Impairment Score (NJIS; Kurtenbach 1990). The NJIS uses family-level taxonomy and an index with three rating categories of biological condition (non-impaired, moderately impaired, and severely impaired). The current protocol may be limited in its ability to detect more subtle degrees of impairment as compared to biological assessments with more detailed taxonomy. NJDEP's original protocol was not developed for perennial headwater streams.

The analyses described in this report are intended to evaluate biological indicators in headwater and non-headwater streams and to recommend an improved index, if the NJIS is not adequate. In 2003, U.S. EPA Region II collected macroinvertebrate samples from headwater streams located in northern New Jersey. Preliminary results of this study showed that these small streams had sufficient macroinvertebrate abundances and taxonomic richness to apply NJDEP's current protocol. However, there was a concern that cut offs for the NJIS metric scores are inappropriate for application in headwater streams. The objective of this study is to analyze recent data of New Jersey streams to recalibrate and revise, if necessary, New Jersey's NJIS index with respect to both headwater and non-headwater streams in high gradient regions of the State. Comparisons will also be made to the recently developed fuzzy set model for predicting tiers of the Biological Condition Gradient (BCG) in New Jersey (Gerritsen and Leppo 2005).

1.1 Study Area

The area of study was limited to northern New Jersey, above the geologic fall-line. This area includes the following ecoregions: the North Central Appalachians, the Central Appalachian Ridges and Valleys, the Northeastern Highlands, the Northeastern Coastal Zone, and the Northern Piedmont. The focus on northern, higher gradient streams was purposeful; it was assumed to reduce variability in the biological samples. Streams in the southern portion of the

State are known to have a fundamentally different character than northern streams. The southern portion is the Mid-Atlantic Coastal Plain, which is different from northern ecoregions in terms of soils, underlying geology, and stream gradients, among other things. A multimetric index was recently developed for Pinelands streams (Jessup et al. 2005) and NJDEP uses the Mid-Atlantic Coastal Streams protocols in non-Pinelands Coastal Plains streams.

1.2 Approach to Index Development

The premise of the index development process is that physical and chemical disturbances are reflected by changes in the benthic macroinvertebrate community. Physical and chemical characteristics can first be used to distinguish minimally disturbed (reference) sites from sites disturbed through human activity. The benthic macroinvertebrate data from these sites can then be used to identify a biological reference condition that is distinct from the non-reference, or stressed, condition. Meaningful biological signals of disturbance are summarized in a multimetric index that can be used to evaluate biological integrity in sites of unknown quality. The development of a multimetric index calibrated on the benthic macroinvertebrate and environmental data collected in high gradient New Jersey streams follows a series of steps, as follows:

1. Collect and organize the data;
2. Define reference and stressed sites;
3. Stratify natural biological conditions;
4. Calculate biological metrics and determine metric sensitivity to stresses;
5. Combine appropriate metrics into index alternatives;
6. Select the most appropriate index for application in high gradient streams based on sensitivity and variability, and;
7. Assess performance of the index.

This report is organized along the lines of the index development process, with methods and results explained for each step. Appendices include site assessments using the recommended index.

2.0 Data Compilation

The NJDEP provided data collected for its AMNET program during the period from 1990 to 2004. These data included benthic macroinvertebrate samples, site and watershed characteristics, field water quality measures, and physical habitat scores. The data were organized in a relational database for efficient storage and calculation of biological metrics. Data from headwater streams collected by U.S. EPA Region II were added to the database so that a combined analysis could be performed. Samples were considered valid for this analysis if they were collected between April 1 and November 1, total individuals in the sub-sample was between 50 and 200, and sites were located in the Appalachian Piedmont and Mountains, above the geologic fall-line (Figure 1).

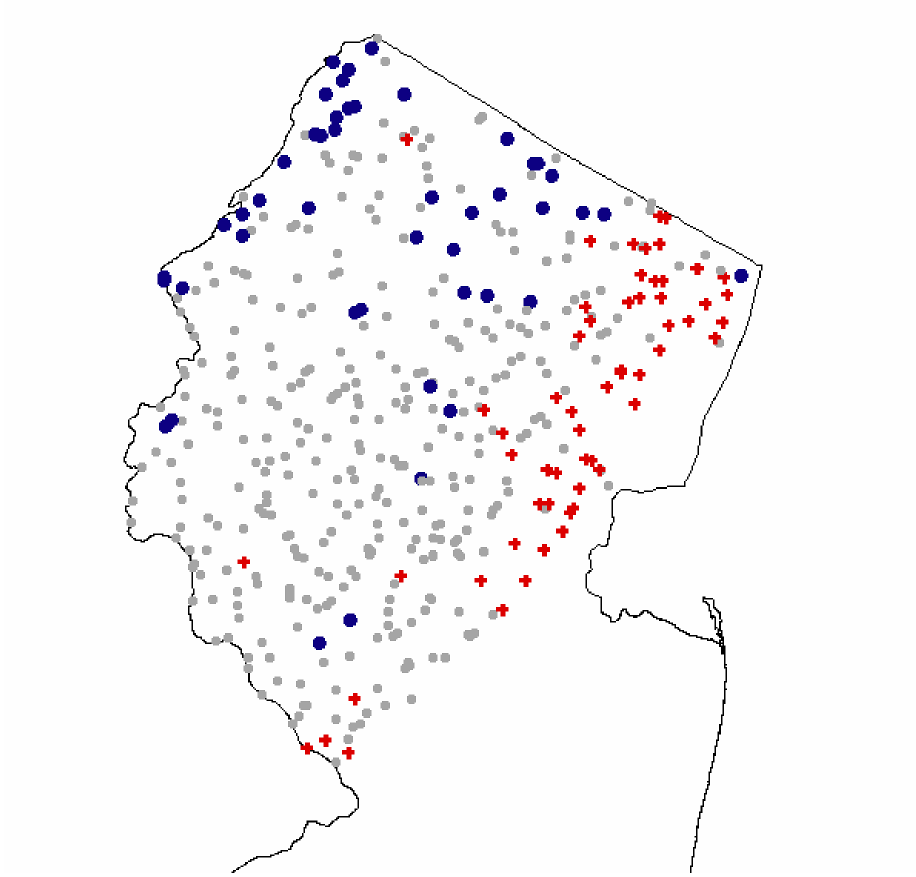

Figure 1. Northern New Jersey showing site locations for samples used in the analysis. Solid circles are least impaired reference sites and crosses are stressed sites. Gray circles are “other” sites, neither reference nor stressed.

NJDEP uses a "multi-habitat" sample collection approach, focusing on the more productive habitat types (Barbour et al. 1999). The usual sampling device is a D-frame kick net of 800 x 900 um mesh size and one foot width. In high-gradient streams, where the predominant substrate is cobble, the riffle/run area is the preferred sampling habitat. The kick net is held firmly against the hard bottom, and an area approximately one foot upstream of the net is disturbed using feet and hands. This procedure is repeated, sampling all velocity/depth regimes at the site, including at least one riffle-run-riffle sequence (if present). The length of the sampling reach approaches, but does not exceed, 100 meters. Level of effort is consistent for all sites. EPA collected samples from riffles over a four minute period. Where possible, samples were taken on the upstream side of any road crossings, sufficiently upstream of the influence of any channel alterations due to bridges. The entire sample is sieved using a #30 mesh sieve bucket, put into wide-mouthed (1-L) jars, and preserved with 5 to 10% formalin or ethanol (to 20% in cases of excessive organic loading).

In the laboratory, the composited sample is rinsed and evenly distributed in a light-colored pan marked with grids of equal size. Using low-power magnification (6.3x), all organisms greater than 2mm in size were removed from randomly selected grids until a total of at least 100 organisms were obtained. EPA processing varies from NJDEP processing in that rose Bengal is added to EPA samples to enhance recognition of specimens during sorting, which is performed without magnification. Also, EPA stops picking after 100 organisms, instead of completely picking a grid, as does NJDEP. Colonial groups (e.g., Bryozoa and Porifera), vertebrates, and terrestrial organisms are not included in the subsample. Organisms were generally of sufficiently good condition to allow for genus level identification.

The individuals from the subsample are identified to the lowest practicable taxonomic level, usually genus or species, using 7 to 30X stereozoom and 40 to 400X compound magnification. A comprehensive collection of taxonomic keys and other references, including functional (or niche) descriptions and pollution tolerance classifications for most species, is maintained in the laboratory. For verification, 10% of the samples are sent to a qualified independent consultant for parallel identifications. A macroinvertebrate specimen reference collection is maintained in the laboratory.

During the field operations, qualitative observations of habitat, surrounding land use, potential pollution sources, and presence of other aquatic biota are recorded. Habitat scores reflect the overall habitat quality as measured using Rapid Bioassessment Protocols (RBP; Barbour et al. 1999). Because habitat scoring methods changed slightly after 1995, scores were standardized as a percentage of the maximum possible score. Field water quality variables include water temperature, dissolved oxygen, specific conductance, and pH. Site characteristics include latitude, longitude, ecoregion, water management area, and hydrologic unit. Watershed characteristics include area of the site catchment, and percentages of land use types in the catchment (urban, agriculture, forest, barren, water, and wetland). Land use coverages were based on remotely sensed data from 1995 and 2002.

The macroinvertebrate samples were collected over several years with repeat visits to established sites over time. To eliminate the chance of biasing the analysis with multiple samples from any one site, one sample per site was selected to be included in the analysis. Samples collected before 1995 were only used if no valid samples were collected after that year. Otherwise, samples were selected randomly from each site.

A multimetric index is a model of collective metric responses to environmental stress. The model is developed, or calibrated, using one set of data. The effectiveness of the model at distinguishing reference from stressed sites is verified using a separate, preferably independent, data set. Samples were assigned to the calibration or verification groups, such that approximately 80% of samples were used in calibration, 20% in verification.

3.0 Defining Reference and Stressed Sites

Reference sites represent least disturbed conditions as determined by non-biological environmental data (Stoddard et al. 2006). They may be sites that have escaped significant human activities that alter stream integrity, or they may have recovered from some past alterations. These sites are not pristine, but are the best sites in this data set and represent a standard that should be attainable for other streams with similar natural characteristics. The variables available in the high gradient dataset for defining reference sites include land use, field chemistry, and habitat assessments. Once reference sites are identified using physical and chemical data, their biological samples are used to describe the biological reference condition, which is a standard to which other samples can be compared for identifying impairment status.

Stressed sites represent conditions that have been degraded by human activities, as measured by physical and land use data. They are expected to have biological samples that differ from reference conditions. Biological metrics with values that consistently differ between reference and stressed sites are apparently responsive to the stressors in the stressed sites. "Other" sites are those classified as neither reference nor stressed. They are expected to have intermediate levels of stress, and are not used in calibration of the index.

3.1 Identifying Reference and Stressed Sites

Reference and stressed sites were selected according to a set of explicit criteria defining what is "best" for the region (Table 1). These criteria were based on recommendations from EPA and NJDEP biologists. The recommendations were tested and modified to arrive at criteria that resulted in a sufficient number of samples for the analysis and that were generally acceptable as indicating least disturbed conditions in the study area. Water quality measures were not used as criteria because the data are assumed to be highly variable with the time of day and date of the samples. EPA suggested specific headwater sites to be included in the reference and stressed data sets, but all of the recommended sites did not meet the modified criteria. Over the period of data collection, the habitat evaluation procedures changed slightly. Earlier evaluations were based on a total possible score of 135 habitat points and later evaluations were based on 200 points. To compare across time periods, the habitat scores were standardized as a percentage of the total possible score.

Table 1. Criteria for reference and stressed sites. Reference sites met all criteria. Stressed sites met any stressed criterion.

Physical Measure	Reference Criteria	Stressed Criteria
% Urban + Agriculture[a]	<20%	>80%
Habitat Score[b]	>75%	<50%
Below Dam	No	

[a] Both 1995 and 2002 data were considered.
[b] As a percentage of the total possible habitat score. Where multiple habitat assessments were recorded, all scores met the criteria (e.g., all > 75% or all < 50%).

3.2 Samples Used in Analysis

Application of reference criteria to 436 high gradient sites in New Jersey resulted in 43 reference sites and 54 stressed sites (Table 2). These sample sizes are large enough to explore site classification in reference sites and to reserve a portion of the data for verification. Reference sites make up 10% of all sites and stressed sites make up 12%, leaving most of the data (78%) uncategorized ("Other"). Four sites were included in the reference data set for ordinations that were removed from later analyses because of close proximity to other reference sites. Information from proximal (and therefore redundant) sites can enhance interpretations of ordinations and can cause bias in metric selection and further steps.

Table 2. Samples available for analysis.

Data Source	All Sites	All Samples	Reference Calibration	Reference Verification	Stressed Calibration	Stressed Verification
AMNET	371	908	18	4	30	7
Headwater	54	54	17	4	13	4
Total	426	962	35	8	43	11

Other than differences in land use coverage and habitat scores, reference and stressed sites differed in specific conductance (Appendix A). Conductivity in reference sites averaged 151 µS/cm (standard deviation 115) and stressed sites averaged 544 µS/cm (standard deviation 200). No differences between reference and stressed sites were evident with pH, water temperature, or dissolved oxygen.

4.0 Site Classification

Strata of biologically similar groups can be identified among high gradient reference sites through examination of biological gradients or assemblage types and association of the biological gradient with natural variables. At the outset of the analysis, we expected that site catchment size might define a natural biological gradient among reference sites. We used non-metric multidimensional scaling (NMS) of the taxonomic data to test our expectations. Additional supporting analyses included indicator species analysis, correlations, cluster analysis, and metric distribution plots. Stratification requires sufficient sample size for development of a multimetric index after separating the reference sites into multiple strata.

4.1 Classification Methods

NMS allows a comparison of taxa within each sample and an arrangement of the samples so that similar samples plot closer together than dissimilar samples in multiple dimensions. Natural environmental variables can be associated with the biological gradient through correlations with the biologically defined axes of the NMS diagram. NMS is a robust method for detecting similarity and differences among ecological community samples and works as well using presence/absence data as relative abundance data (McCune and Mefford 1999).

A site by taxa matrix was compiled. Similarity among reference biological samples was made using the Bray-Curtis similarity measure. The Bray-Curtis (BC) formula is sometimes written in shorthand as

$$BC = 1-2W/(A+B)$$

where W is the sum of shared abundances and A and B are the sums of abundances in individual sample units. The ordination software (PC-Ord, McCune and Mefford 1999) calculates a site by site matrix of BC similarity from which the arrangement of samples in the ordination diagram is derived. Multiple dimensions are compressed into two or three dimensions that we can perceive.

Rare and ambiguous taxa are not useful in the NMS ordination. Rare taxa were defined as those that occurred in less than three reference samples. Ambiguous taxa are those that are identified at higher taxonomic levels because of damaged or undeveloped specimens. The site by taxa matrix was therefore reduced to retain as much information as possible while excluding rare and ambiguous taxa. When several rare genera occurred within one family or when several identifications were at the family level, then all individuals were counted at the family level. When most identifications within a family were made at genus level, then the fewer identifications made at family level were excluded from the analysis. The site by environmental variable matrix included location information and catchment characteristics.

4.2 Classification Results

In classification, the goal is to identify differences among biological samples that can be attributed to natural differences among their sites. The environmental variables available for testing included catchment size, latitude, longitude, ecoregion, hydrologic unit, and water management area. Other variables were available for exploring effects of human disturbance (land use, water quality, and habitat), but these are not appropriate for classification. Sampling metadata were also available (sampling agency and date of sample), which are also not appropriate for classification, but could illustrate sampling effects.

Ordination
In the NMS ordination, the strongest classification variable was catchment size category. This is evident when comparing samples based on presence/absence of taxa. In the presence absence diagram of sites in taxa space, the core area of small sites (less than 10 square kilometers) is not overlapped by any of the largest sites (greater than 40 sq. km.) on the two most important axes of the ordination diagram (Figure 2). About a third of the smallest sites were outside of the core area of their group and intermingle with the medium and large sites. Groupings based on size class or other variables were not as obvious using relative abundance information. This suggests that differences among the catchment size classes are due to taxa of low abundances in the samples.

The smaller sites have more representation by the Plecoptera (stoneflies). Non-insects are more common in larger sites. Smaller sites have lower pH, ranging from 6.5 – 8.0, compared to larger sites with pH’s mostly greater than 7.5. In general, in the smaller sites, dissolved oxygen is lower and temperature is higher. EPA headwater samples were collected in July, when higher temperatures can be expected.

The variable that showed greatest discriminating power in the presence/absence NMS diagram was the sampling agency – NJDEP or EPA. This is not a valid classification variable, but it suggests that there may have been differences in the samples based on site selection, sample collection techniques, processing and identification methods, or sampling dates. The pattern was not observed in relative abundance NMS ordinations.

Indicator Species Analysis

Further investigation using an indicator species analysis (Dufresne and Legendre 1997) on reference sites of less than 20 square kilometers revealed that there are several taxa occurring in the NJDEP samples that were not observed in any of the EPA samples (Table 3). Some of the indicator taxa that are more prevalent in NJDEP samples are from relatively slow-water habitats (Tubificidae, Isopoda, Sphaeriidae, Cryptochironomus, Phaenopsectra), suggesting that EPA concentrated sampling in riffles to a greater degree than NJDEP. Distributions of metrics based on insects and their attributes appear similar when comparing NJDEP and EPA samples. Metrics based on non-insects showed that NJDEP samples captured more non-insect taxa as a percentage of all taxa. This effect is less pronounced when calculating percent of non-insect taxa at the family level (Figure 3).

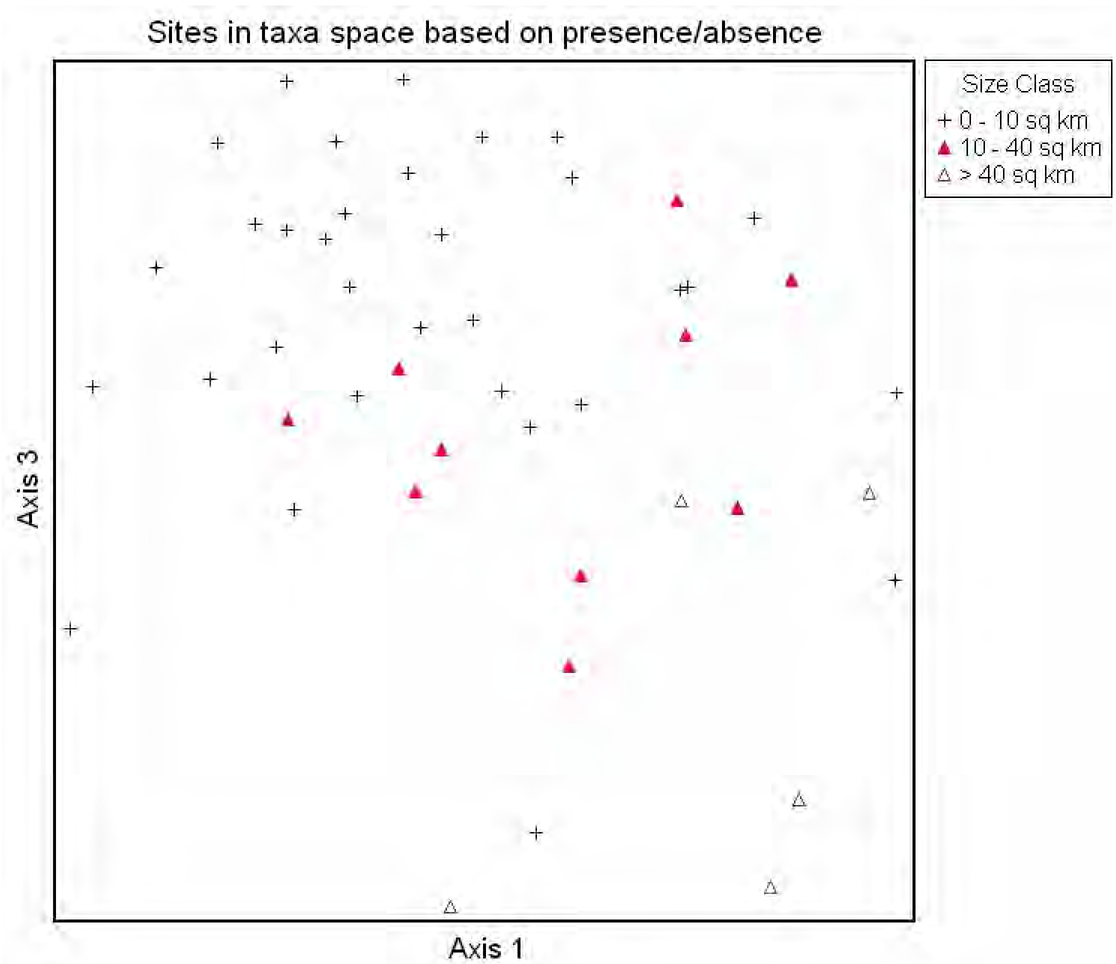

Figure 2. NMS diagram of reference sites arranged by taxonomic similarity and indicating the catchment size class for each site. The diagram includes four sites that were removed from later analyses.

Table 3. Taxa occurring in greater frequencies and abundances by collecting agency. This partial list shows only those taxa that showed significant indications ($p<0.05$) among small reference sites (< 20 sq. km.).

More common in NJDEP samples	More common in EPA samples
Centroptilum* (Baetidae)	Pteronarcyidae (Pteronarcyidae)
Cryptochironomus* (Chironomidae)	Parametriocnemus (Chironomidae)
Stenacron* (Heptageniidae)	Orthocladius (Chironomidae)
Isopoda* (Isopoda)	Ectopria (Psephenidae)
Leptoceridae* (Leptoceridae)	Polypedilum (Chironomidae)
Nemertea* (Nemertea)	Tvetenia (Chironomidae)
Agnetina* (Perlidae)	Acroneuria (Perlidae)
Sphaeriidae (Sphaeriidae)	Rhyacophila (Rhyacophilidae)
Tubificidae (Tubificidae)	Oulimnius (Elmidae)
Phaenopsectra (Chironomidae)	Dolophilodes (Philopotamidae)
Stenelmis (Elmidae)	

* Taxa entirely absent from EPA samples.

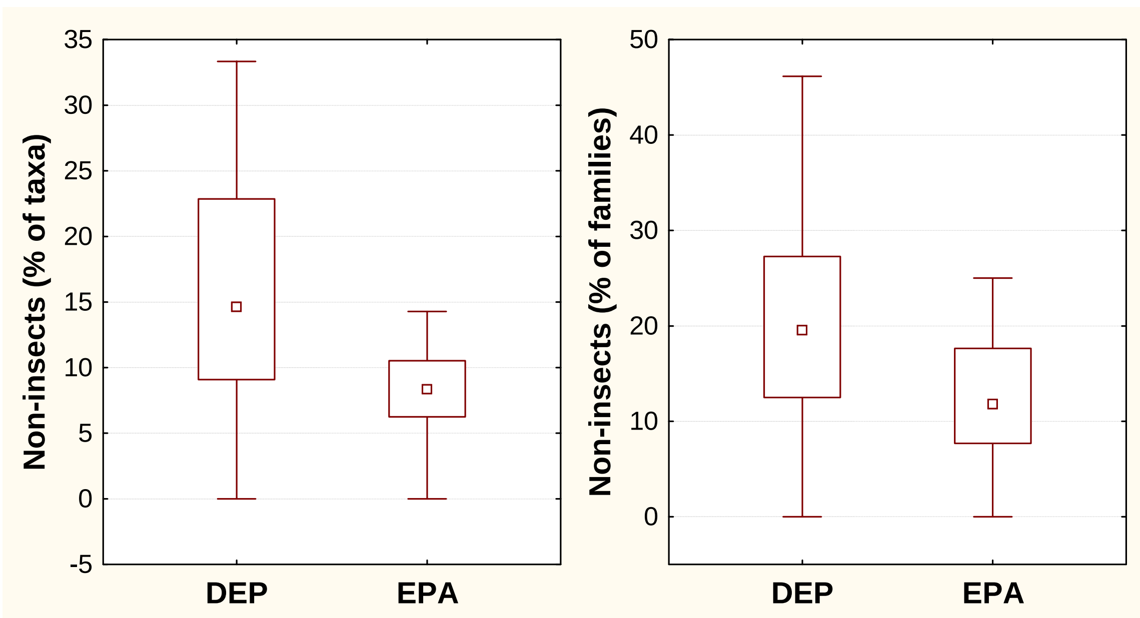

Figure 3. Non-insect metric distributions by sampling agencies.

Cluster Analysis

A cluster analysis was conducted and a discriminant function analysis (DFA) was used to explore classification variables for 3 – 5 groups. With 5 groups, only catchment area (log transformed) entered into the model at a significance level of $p<0.05$. With 3 groups, log catchment area and latitude entered into the model. Latitude is related to ecoregions, with the piedmont in the south and the Appalachian Mountains, ridges, and valleys in the north. However, within the study area, most reference sites are in the northwest and more stressed sites are in the southeast, confounding the natural variable with influences of human disturbance and rendering latitude an unreliable group predictor for this analysis.

Metric distributions by size class
Box and whisker plots were used to illustrate metric differences among catchment size classes. Metric distributions are similar among the groups (Figure 4). The samples from sites in the smallest size class have slightly fewer scraper taxa and samples from sites in the largest size class have slightly higher HBI values and a greater percentage of non-insect taxa. These differences are not significant. Sites with large catchments make up the smallest site class (too small to calibrate an independent index: 5 sites).

Correlations
Using reference calibration and verification data, 26 metrics had significant correlations with catchment size (log of square kilometers). Significant regression coefficient (r^2) values ranged from 0.093 to 0.225 (Table 4). The strongest correlation was with the biotic index based on Biological Condition Gradient (BCG) attributes.

Classification Conclusions
There is evidence that stream catchment size affects metric values. No other variables were identified as useful for site classification. NMS ordination and distribution plots of metrics show that the smallest streams may have different organisms and compositions compared to the largest streams. Scatter plots of metric values and catchment size reveal no obvious “breakpoints” that could be used to discretely classify sites by size class. Correlation analysis shows that most metrics are unaffected by catchment size. However, for certain metrics catchment area can explain up to 23% of metric variability in reference sites. Therefore, adjustment of the individual metrics that respond to catchment size using a continuous (not categorical) scale would be the best alternative for recognizing biological variability due to catchment size. Metrics and indices can be adjusted for watershed area using the following formula:

adjusted metric = mean reference value + observed value – predicted value,

where the predicted value is derived from a regression of reference values (both calibration and verification data) on catchment size (log of square kilometers).

Most of the reference data are from streams with catchment sizes between 2 and 50 square kilometers. Stressed sites are also mostly in this range. Among sites that are neither reference nor stressed, there are several that are larger than 50 square kilometers and a few that are smaller than 2 square kilometers. Extrapolation of catchment size effects outside of the range of calibration (2 – 50 square kilometers) may yield imprecise metric predictions. This has not been tested.

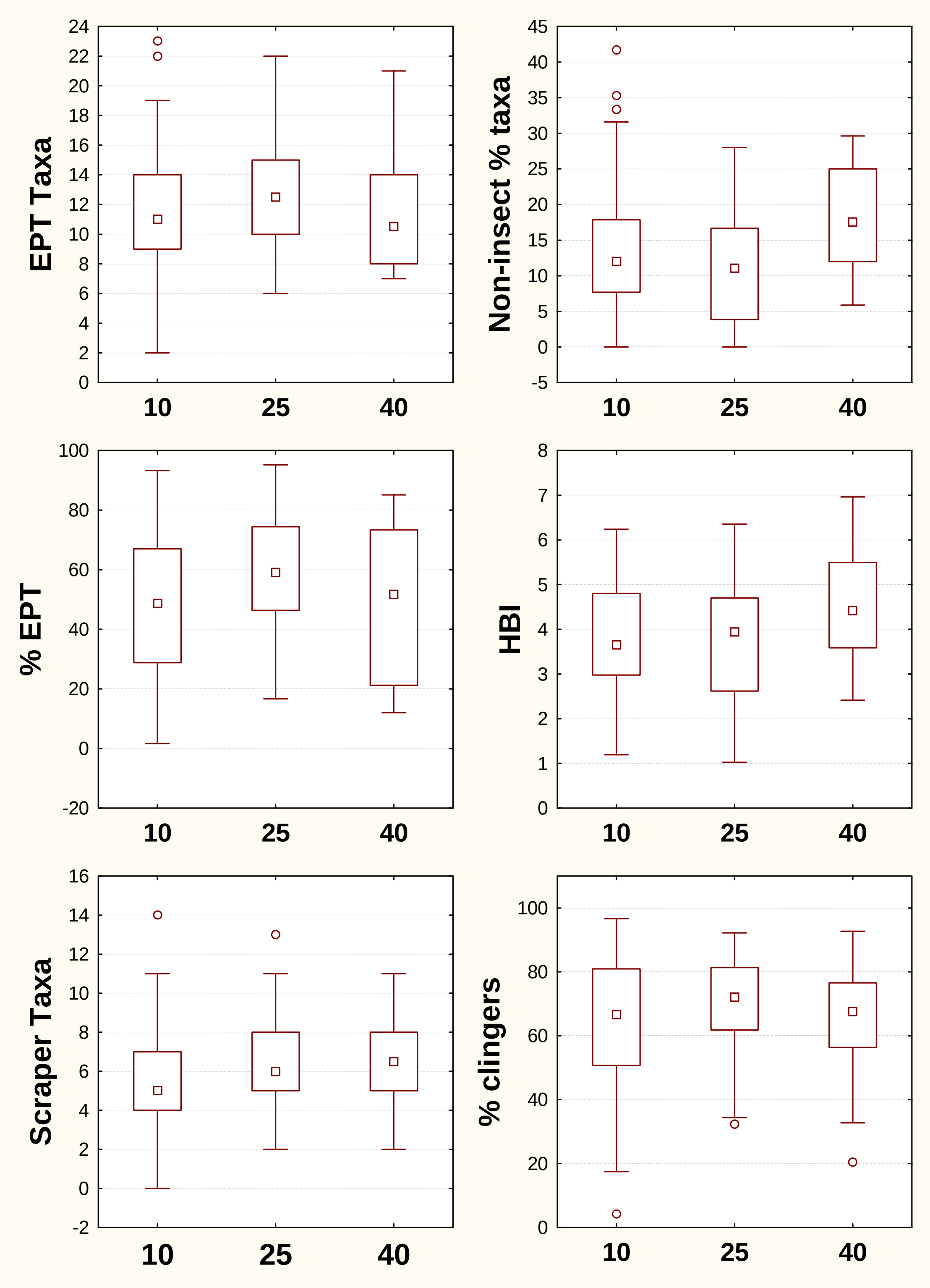

Figure 4. Metric distributions in reference sites of three size classes.

Table 4. Correlation (r) and regression (r^2) coefficients of metrics significantly ($p<0.05$) related to catchment area (log square kilometers) in reference data.

Metric	r	r^2	Metric	r	r^2
Total Taxa	0.33	0.11	Margalef's Diversity	0.31	0.10
Ephemeroptera Taxa	0.44	0.19	Scraper Taxa	0.31	0.09
Ephemeroptera Taxa @ family	0.39	0.15	Collector Taxa	0.34	0.11
Plecoptera Taxa @ family	-0.42	0.17	Swimmer Taxa	0.40	0.16
Crustacea & Mollusca Taxa	0.41	0.17	Clinger Taxa	0.37	0.14
% EPT excluding Hydropsychidae	-0.32	0.10	% Sprawler	-0.39	0.15
% EPT excl. Hydropsychidae including Diplectrona	-0.36	0.13	Hilsenhoff's Index	0.43	0.18
% EPT excluding Hydropsychidae and Baetidae	-0.33	0.11	Hilsenhoff's Index @ family	0.34	0.12
% Isopoda	0.33	0.11	Biotic Index (BCG taxa)	0.32	0.10
% Tubificidae	0.34	0.11	Biotic Index (BCG individuals)	0.47	0.23
Cricotopus&Chironomus/ Chironomidae	0.31	0.09	% Tolerant	0.42	0.17
% BCG attr 2	-0.40	0.16	% Intolerant	-0.31	0.09
BCG attr 4 taxa	0.42	0.18	Tolerant Taxa	0.37	0.13
% BCG attr 4	0.33	0.11			

5.0 Metric Calculations and Responses to Stress

A biological metric is a numerical expression of a biological community attribute that responds to human disturbance in a predictable fashion. Metrics were considered for inclusion in this multimetric index on the basis of discrimination efficiency, low inter-annual or seasonal variability, ecological meaningfulness, contribution of representative and unique information, and sufficient range of values. They were organized into seven categories: richness, composition, evenness, pollution tolerance, BCG attributes, functional feeding group, and habit (mode of locomotion).

5.1 Metric Methods

A suite of commonly applied, empirically proven, and theoretically responsive metrics was calculated for possible inclusion in a multimetric index. Tolerance metrics were based on both Hilsenhoff tolerance values and Biological Condition Gradient (BCG) taxa attribute groups (Davies and Jackson 2006; Gerritsen and Leppo 2005). Hilsenhoff tolerance values are on a 0 to 10 scale (most sensitive to most tolerant). The Hilsenhoff scale was derived primarily to address taxa tolerance to organic pollutants (Hilsenhoff 1987). Attributes associated with taxa for BCG analysis range from sensitive-endemic to pollution tolerant. BCG attributes were assigned to taxa by consensus during a workshop on assessment of New Jersey's wadeable streams (Gerritsen and Leppo 2005). Several metrics describe richness and composition of Ephemeroptera, Plecoptera, and Trichoptera (EPT; mayflies, stoneflies, and caddisflies) insects.

All richness metrics (e.g., insect taxa and non-insect taxa) were calculated such that only unique taxa are counted. Those taxa that were identified at higher taxonomic levels because of damage or under-developed features were not counted as unique taxa if other individuals in the sample were identified to a lower taxonomic level within the same sample. Genus level taxonomy was expected to provide more responsive metrics, so all metrics were calculated at the genus level. Metrics that performed well or were previously part of the NJIS were also calculated at the family level. Metrics were not calculated at the species level because several specimens were not identified below genus. Collapsing to genus level provides greater taxonomic consistency, though species level attributes are lost. Habit metrics were calculated using insect taxa only. Habit attributes were not assigned to non-insects by NJDEP. Metrics were calculated in a relational database. Once calculated, the metrics were imported into the statistical package Statistica for further analysis.

Discrimination efficiency
Discrimination efficiency (DE) is the capacity of the biological metric or index to detect stressed conditions. It is measured as the percentage of stressed sites that have values lower than the 25th percentile of reference values (Stribling et al. 2000). For metrics that increase with increasing stress, DE is the percentage of stressed sites that have values higher than the 75th percentile of reference values. DE can be visualized on box plots of reference and stressed metric or index values with the inter-quartile range plotted as the box (Figure 5). When there is no overlap of boxes representing reference and stressed sites, the DE is greater than 75%. A metric with a high DE thus has a greater ability to detect stress than metrics with low DEs. Metrics with DEs <25% do not discriminate and were not considered for inclusion in the index.

Metric variability
When comparing metrics, those with lower variability in the reference sites are preferable to those with higher variability. Variability was measured as the coefficient of variability (CV) in reference sites, calculated as the metric standard deviation over the mean, expressed as a percentage. Lower CVs indicate greater precision of metrics.

Other metric considerations
Ecologically meaningful metrics are those for which the assemblage response mechanisms are understandable and are represented by the calculated value. Ecological meaningfulness is a professional judgment based on theoretical or observed response mechanisms. Those metrics that respond according to expectations established in other studies are more defensible.

Metrics contribute information representative of integrity if they are from diverse metric categories. As many metric categories as practical should be represented in an index so that signals of various stressors can be integrated into the index. While several metrics should be included to represent biological integrity, those that are included should not be redundant with each other. Redundancy was evaluated using a Pearson Product-Moment correlation analysis.

For metrics to discriminate on a gradient of stress, they must have a sufficient range of values. Metrics with limited ranges (e.g., richness of taxa poor groups or percentages of rare taxa) may have good discrimination efficiency. However, small metric value changes will result in large and perhaps meaningless metric scoring changes.

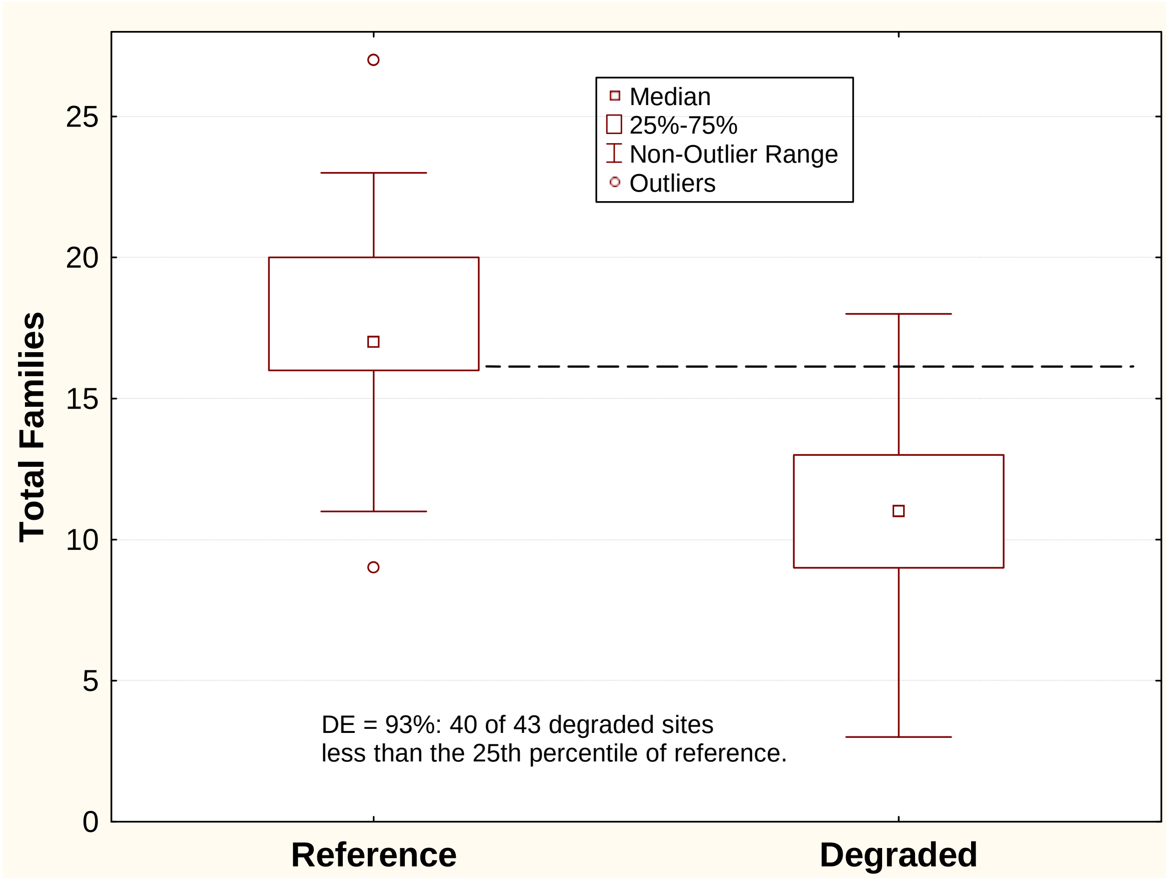

Figure 5. Illustration of metric discrimination efficiency (DE) between reference and stressed sites.

5.2 Metric Results

One hundred and nineteen (119) metrics were calculated in the seven metric categories (Appendix B). Within calibration samples, 90 metrics responded with at least 50 percent of stressed sites worse than the 25th or 75th percentile of reference. Metrics were excluded from consideration in possible index alternatives if they did not discriminate or discriminated weakly between reference and stressed sites, were redundant with more discriminating metrics, or were not representative of the benthic community. The habit metrics were not representative (and were not used) because habit attributes were only assigned to insect taxa. Box plots of metric distributions in reference and stressed samples of the calibration data set show that several metrics clearly discriminate between reference and stressed sites (Appendix C).

In general, metrics based on sensitive taxa were more responsive to increasing stress than metrics based on tolerant taxa. For instance, BCG metrics based on attributes 2 and 3 had higher DEs than those based on attributes 4 or 5. In the richness and composition categories, the most responsive metrics included those based on sensitive insects (mayflies, stoneflies, and caddisflies).

Metrics based on pollution tolerance had excellent DE's, with several showing DE's greater than 90%. Feeding group metrics based on scrapers were more discriminating than other feeding groups. Evenness metrics based on the entire sample performed better than simple percent dominance. Habit metrics based on clingers performed best in the category. Habit attributes were only assigned to insects and clingers were highly correlated with EPTs. For these reasons, habit metrics were not used in the index. For metrics with higher DE's, family level metrics performed the same as their genus level counterparts (DE's within 5%).

6.0 Index Composition

A multimetric index is a combination of metric scores that indicates a degree of biological stress in the stream community (Barbour et al. 1999). Individual metrics are candidate for inclusion in the index if they:

- discriminate well between reference and stressed sites;
- are ecologically meaningful (mechanisms of responses can be explained);
- represent diverse types of community information (multiple metric categories); and
- are not redundant with other metrics in the index.

Metrics are scored on a common scale prior to combination in an index. The scale ranges from 0 to 100 and the optimal score is determined by the distribution of data. For metrics that decrease with increasing stress, the 95th percentile of all high gradient data was considered optimal and scored as 100 points. All other metric values were scored as a percentage of the 95th percentile value (Figure 6) except those that exceeded 100, which were assigned a score of 100. The 95th percentile value was selected as optimal instead of the maximum so that outlying values would not skew the scoring scale.

6.1 Index Results

To accommodate differing needs and capabilities across monitoring programs throughout the high gradient region of New Jersey, two indices were developed; one at genus level and another at family level. Several index alternatives were calculated using an iterative process of adding and removing metrics, calculating the index, and evaluating index responsiveness and variability (Appendix D). The first index alternatives included variations of the family level NJIS. Other index alternatives were composed of those metrics that had the highest DEs within each metric category. Subsequent index alternatives were formulated by adding, removing, or replacing one metric at a time from the initial index alternatives that performed well. Indices were tested using metrics at both genus and family levels. The index alternatives recommended as the High Gradient Macroinvertebrate Index (HGMI at genus and family levels) were those that met the criteria listed above and that could not be improved (increased DE, lower variability) by substituting, adding, or removing metrics. Each alternative index was evaluated based on discrimination efficiency (DE, calculated as for individual metrics), separation of reference and stressed index means as a multiple of the inter-quartile range of reference scores (quartile Z score), and the Mann-Whitney non-parametric Z score.

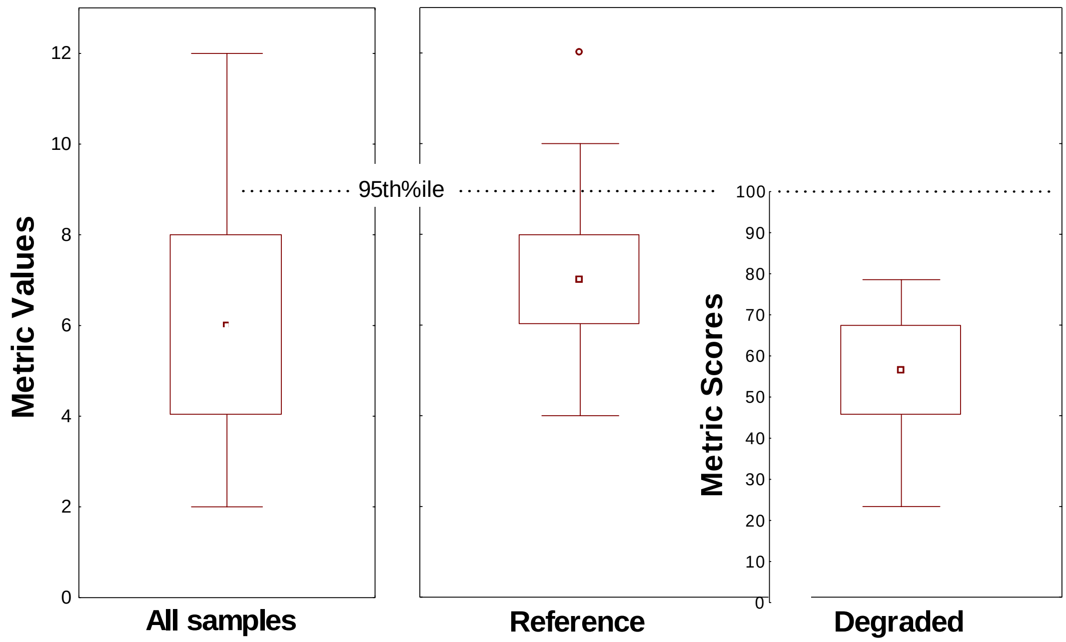

Figure 6. Metric scoring schematic for metrics that decrease with increasing stress. For metrics that increased with increasing stress (not shown), the 5th percentile of the data was considered optimal and assigned a value of 100 points, with increasing values scaled down to 0.

The index recommended as the $HGMI_{gen}$ includes the following metrics:

- Total number of genera
- Percent of genera that are not insects[1]
- Percent of sensitive EPT individuals (excluding Hydropsychidae, including Diplectrona)
- Number of scraper genera
- Hilsenhoff Biotic Index
- Number of attribute 2 genera
- Number of attribute 3 genera

The index recommended as the $HGMI_{fam}$ includes the following metrics:

- Number of EPT families
- Percent of families that are not insects[1]
- Percent of individuals that are EPT (excluding Hydropsychidae)
- Number of scraper families
- Family Biotic Index

[1] The "percent of genera (families) that are not insects" metrics are calculated from taxa counts, not individual abundance. A sample with four non-insect taxa and 16 taxa overall would have a metric value of 25%.

For comparison, the NJIS contains the following metrics: total number of families, number of EPT families, percent EPT, percentage of individuals in the dominant family, and the family biotic index. The revised indices show better discrimination than the original NJIS, partly because the percent dominant metric does not perform well in this data set. In addition, the percent EPT metric performs better when eliminating Hydropsychidae from the calculation and the metrics based on BCG attributes are highly discriminating.

Four of the metrics in the $HGMI_{gen}$ and two of the metrics in the $HGMI_{fam}$ were significantly correlated with catchment area. These were adjusted prior to scoring based on linear regressions (Table 5), as recommended in the classification discussion (Section 4.2).

Table 5. Adjustments to metric values to account for catchment size.

Metric adjustment formula[A]	Index
Total genera $_{adj}$ = 26.53 + Metric - (22.776 + 4.173*log10(areasqkm))	Genus
Scraper genera $_{adj}$ = 5.44 + Metric - (3.889 + 1.724*log10(areasqkm))	Genus
% sensitive EPT $_{adj}$ = 37.49 + Metric - (49.922 - 13.800*log10(areasqkm))	Genus
%EPT (no Hydropsychidae) $_{adj}$ = 35.15 + Metric - (45.59 - 11.59*log10(areasqkm))	Family
Hilsenhoff Biotic Index $_{adj}$ = 4.23 + Metric - (3.407+0.918*log10(areasqkm))	Genus
Family Biotic Index $_{adj}$ = 4.19+ Metric - (3.636 + 0.615*log10(areasqkm))	Family

[A] Adjusted metric value = $Mean_{Reference}$ + $Metric_{Observed}$ - $Metric_{Predicted}$, where predictions are based on linear regression analysis of reference metric values on catchment size.

Performance statistics and scoring formulas of the HGMI metrics (Table 6) will allow application and interpretation of the index. Investigators should calculate scores from sample taxa lists and average the scores to arrive at the appropriate index value.

Metrics that performed well but were not selected for the recommended genus level index included metrics based on the EPT genera, because they were redundant with metrics based on attribute 2 and 3 taxa. The strongest correlation among index metrics was between % sensitive EPT and the Hilsenhoff Biotic Index, with a correlation coefficient of -0.81 (Table 7). This level of redundancy is at the upper limit of acceptability.

Metrics that performed well but were not selected for the recommended family level index included several metrics that were highly correlated with EPT families, such as clinger taxa, intolerant taxa, Beck's Biotic Index, and BCG Attribute 2 and 3 taxa. The highest correlation among index metrics was between EPT families and non-insect families as a percent of all families, with a Pearson product moment correlation coefficient of -0.80 (Table 8). This level of redundancy is at the upper limit of acceptability.

Table 6. Performance statistics and scoring formulas for index metrics.

Metric	Index	CV [1]	DE [2]	Response [3]	Scoring Formula [4]
Number of genera [5]	Genus	21.8	79.1	Dec	100* X /31
% non-insect genera	Genus	62.0	90.7	Inc	100*(60- X)/55
% sensitive EPT [5]	Genus	46.2	93.0	Dec	100* X /69
Number of scraper genera [5]	Genus	48.4	81.4	Dec	100* X /11
Hilsenhoff Biotic Index [5]	Genus	22.4	95.3	Inc	100*(7.2- X)/4.6
Number of attribute 2 genera	Genus	52.7	100.0	Dec	100* X /8
Number of attribute 3 genera	Genus	43.9	97.7	Dec	100* X /8
Number of EPT families	Family	29.7	95.3	Dec	100* X /12
% non-insect families	Family	59.9	95.3	Inc	100*(70- X)/63
% EPT (no Hydropsychidae) [5]	Family	47.9	93.0	Dec	100* X /67
Number of scraper families	Family	34.2	81.4	Dec	100* X /6
Family Biotic Index [5]	Family	19.5	90.7	Inc	100*(7- X)/4

[1] CV = Coefficient of Variability = 100*$StdDev_{Ref}$ / $Mean_{Ref}$.

[2] DE = Discrimination Efficiency = percentage of stressed samples with metric values outside of the reference quartile range in the direction of response (calibration data only).

[3] Direction of metric response with increasing stress, decreasing (Dec) or increasing (Inc).

[4] "X" refers to the appropriate metric value. The scoring range is between 0 and 100. If formula results in a value outside of the range, reset the score to the nearest extreme of the range.

[5] See Table 5 for metric adjustment prior to scoring.

Table 7. Correlation coefficients (Pearson product-moment) among metrics of the $HGMI_{gen}$ (adjusted as required, calibration and verification data).

#	Metric	1	2	3	4	5	6	7
1	Total genera	•						
2	% non-insect genera	-0.42	•					
3	% sensitive EPT	0.19	-0.56	•				
4	Number of scraper genera	0.70	-0.38	0.36	•			
5	Hilsenhoff Biotic Index	-0.10	0.61	-0.81	-0.31	•		
6	Number of attribute 2 genera	0.55	-0.59	0.57	0.54	-0.52	•	
7	Number of attribute 3 genera	0.62	-0.64	0.62	0.64	-0.57	0.62	•

Table 8. Correlation coefficients (Pearson product-moment) among metrics of the $HGMI_{fam}$ (adjusted as required, calibration and verification data).

#		1	2	3	4	5
1	EPT families	•				
2	% non-insect families	-0.80	•			
3	% EPT (no Hydropsychidae)	0.74	-0.63	•		
4	Scraper families	0.73	-0.56	0.61	•	
5	Family Biotic Index	-0.62	0.63	-0.72	-0.57	•

6.2 Index Performance

The recommended indices discriminate well between reference and stressed sites. All of the index scores from stressed sites are below the 25th percentile of reference sites (DE = 100%, Figure 7 - 8). Discrimination statistics for other percentiles of the reference distribution (Table 9) allow consideration of Type 1 and Type 2 errors for assessment thresholds. For the genus index, error would be minimized at a threshold based on the 5th percentile of reference. At this threshold the total error rate is 9%; 5% Type 1 and 4% Type 2. For the family index, error would be minimized at a threshold based on the 10th percentile of reference. At this threshold the total error rate is 12%; 10% Type 1 and 2% Type 2.

The reference data set includes an outlier that appears in several of the index alternatives. The outlier is site AN0225, an unnamed tributary of the Dead River, which is the lowest reference in both genus and family indices. This site was established as an ecoregional reference site in the early 90's, but NJDEP biologists have noticed a significant decline in the site in the last 10 years. The cause of this decline has not yet been determined. The highest index value of the stressed sites is site AN0086, Lockatong Creek, for both indices.

Table 9. Index discriminations based on several percentiles of the reference distribution (calibration and verification data).

Statistic \ Percentile	Index	0th (min)	5th	10th	15th	20th	25th	50th (median)
Reference value (N = 43)	Genus	29.11	44.3	46.2	54.1	56.0	60.4	69.1
% stressed below (N = 54)	Genus	66.7	96.3	98.1	100	100	100	100
Reference value (N = 43)	Family	26.6	43.2	50.2	57.8	61.0	63.0	69.4
% stressed below (N = 54)	Family	70.4	88.9	98.1	98.1	100	100	100

Other performance measures used to compare alternative index formulations are marginally superior for the recommended indices (Appendix D). These measures include the quartile Z-score and the Mann-Whitney Z-score, both of which account for both separation of values between reference and stressed sites and variability in the values. The quartile Z-score for the genus level index is higher than any for family level index alternatives.

Variability measured within repeated samples (samples taken over multiple seasons and years in sites all along the stressor gradient) indicates that the $HGMI_{gen}$ has a 90% confidence interval of ±15.1 index points and a CV of 20.1%. The $HGMI_{fam}$ has a 90% confidence interval of ±18.1 index points and a CV of 21.2%. When the index CV is measured among reference sites it is 22.2% for both the genus and family indices. The CV's of the recommended indices are lower than those of several other index alternatives.

HGMI index values are generally in agreement with Biological Condition Gradient (BCG) tiers as determined using the fuzzy set model of Gerritsen and Leppo (2005, Figures 9 and 10). There is complete separation of the HGMI inter-quartile ranges between tiers 2, 3, 4, and 5, especially for the $HGMI_{gen}$. Inter-quartile overlap was somewhat higher for tiers 2 and 3 in the family index. Sample sizes for the half-tiers and tier 6 are too small to reliably interpret.

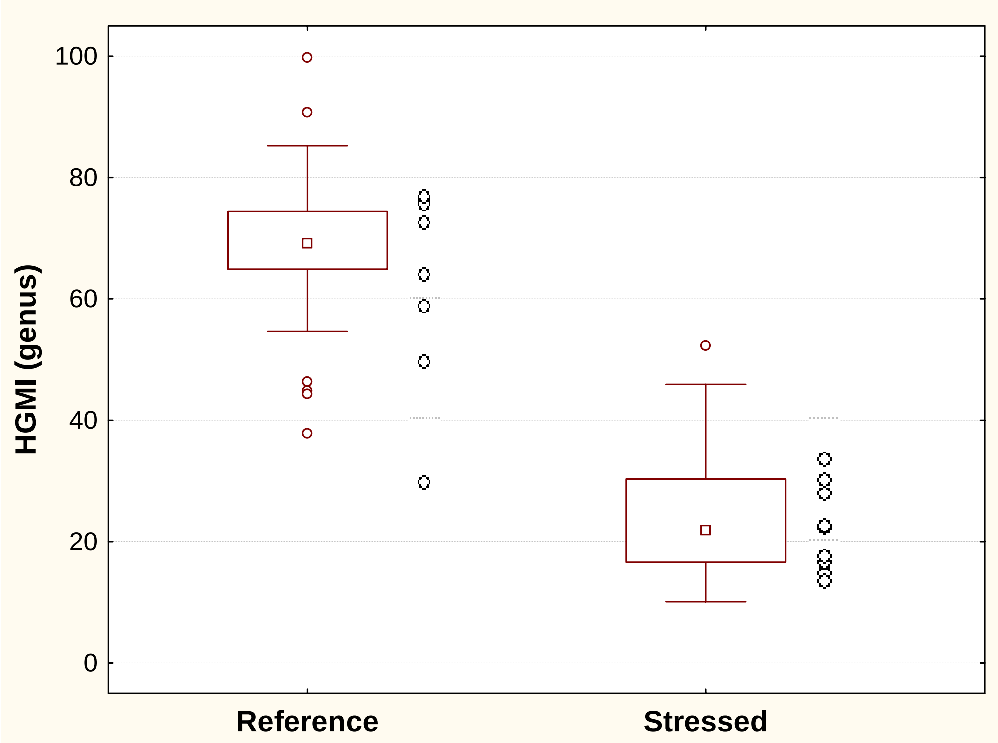

Figure 7. Distribution of $HGMI_{gen}$ values in reference and stressed sites. Box plots describe distributions of calibration data. Verification data are represented by individual points.

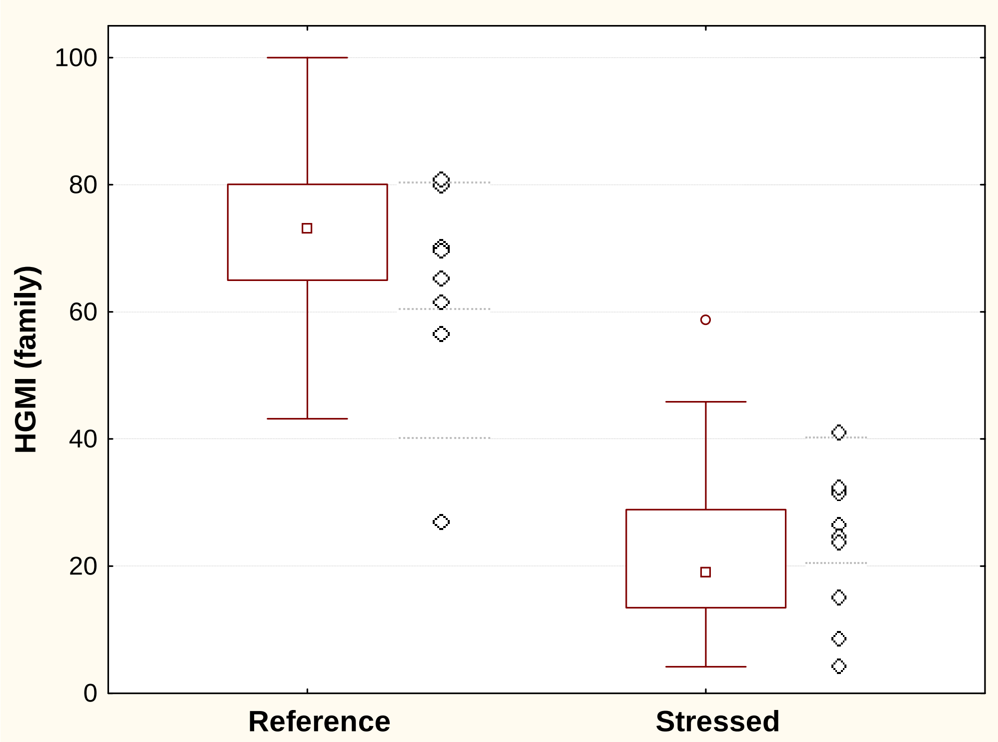

Figure 8. Distribution of $HGMI_{fam}$ values in reference and stressed sites. Box plots describe distributions of calibration data. Verification data are represented by individual points.

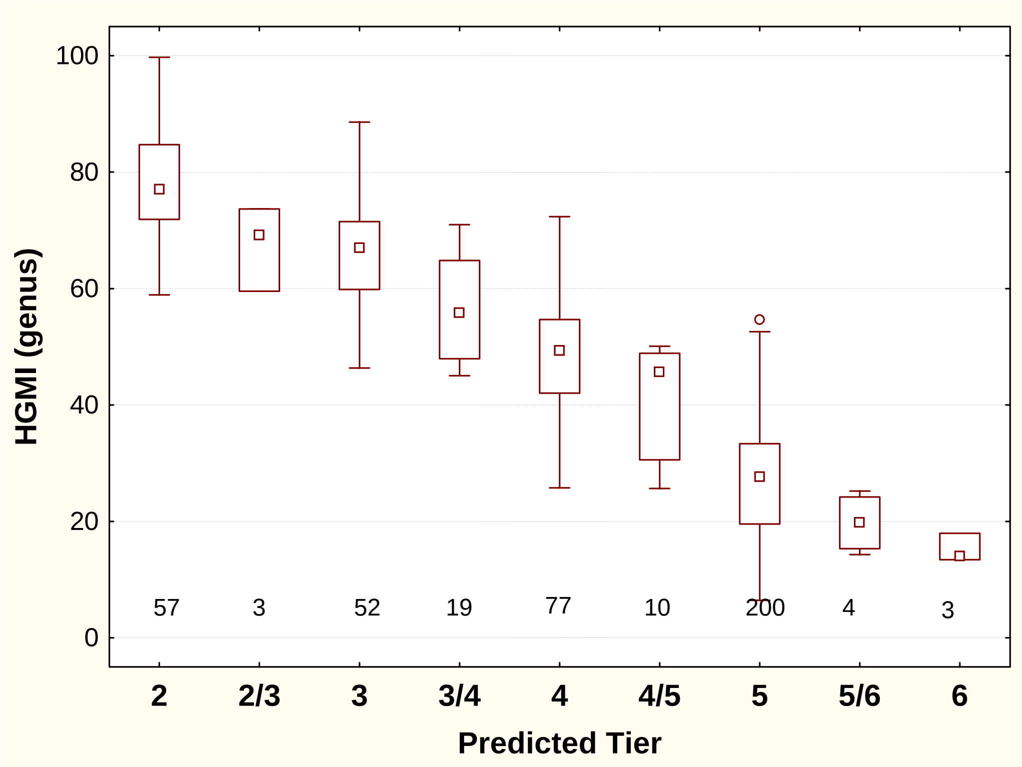

Figure 9. HGMI$_{gen}$ value distributions within categorical BCG tiers resulting from the fuzzy set model. This figure includes all calibration and verification data. Sample sizes are shown above Tier labels.

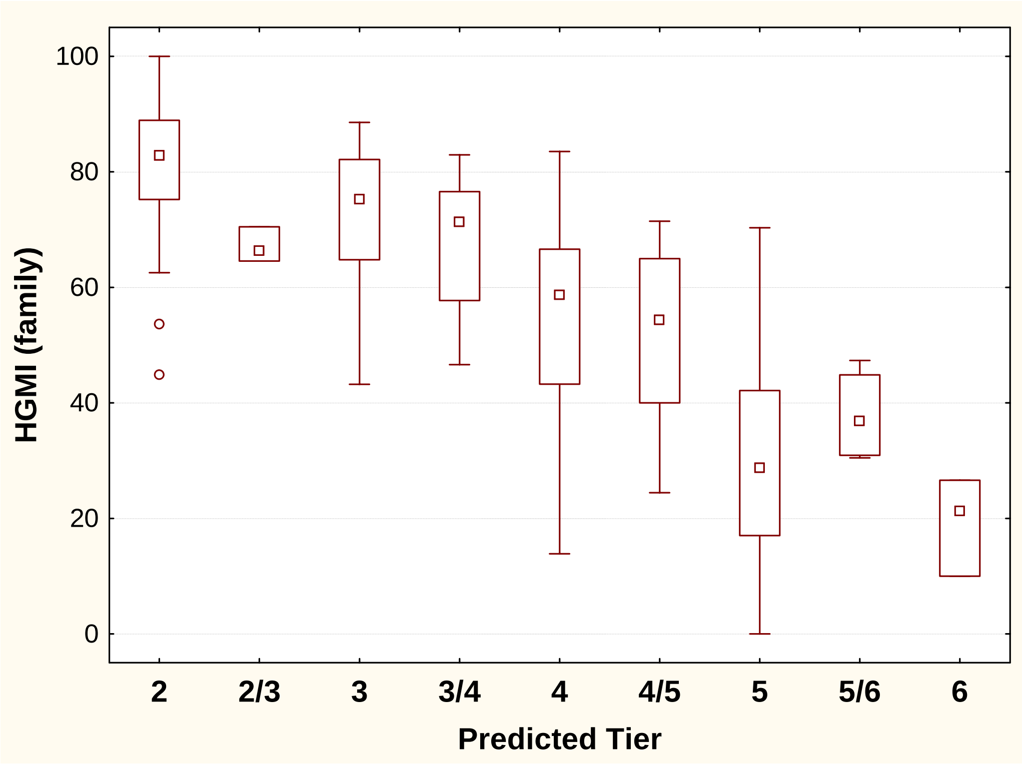

Figure 10. HGMI$_{fam}$ value distributions within categorical BCG tiers resulting from the fuzzy set model. This figure includes all calibration and verification data. Sample sizes are as shown in Figure 9.

7.0 Conclusions

The High Gradient Macroinvertebrate Index (HGMI) was developed as a tool for identifying biological degradation in the high gradient streams of New Jersey. Two indices were developed, one for application with genus level taxonomy and one for family level data. For the $HGMI_{gen}$, seven metrics are calculated and scored for inclusion in the index, including:

- Total number of genera
- Percent of genera that are not insects
- Percent of EPT individuals (excluding Hydropsychidae, including Diplectrona)
- Number of scraper genera
- Hilsenhoff Biotic Index
- Number of attribute 2 genera
- Number of attribute 3 genera

Five metrics are calculated and scored for inclusion in the $HGMI_{fam}$, including:

- Number of EPT families
- Percent of families that are not insects
- Percent of individuals that are EPT (excluding Hydropsychidae)
- Number of scraper families
- Family Biotic Index

For combined calibration and verification data, all stressed sites had HGMI scores lower than the 25^{th} percentile of reference scores (DE = 100%). The $HGMI_{gen}$ is more precise than the $HGMI_{fam}$ and should be used when taxonomic expertise for reliably identifying genera is available.

The HGMI accounts for natural variability through metric adjustments of those metrics that were correlated with catchment area (see Table 5), the only natural environmental variable that had any significant effect on metrics in reference sites. There is no categorical classification by stream size. Rather, metrics are adjusted on a continuous scale using the regression relationships between metric values and catchment size in reference sites.

The selection of threshold values that are protective of aquatic life uses is the responsibility of the State. An indication that aquatic life uses are attained can come from comparison of index values among new samples and the reference data from this data set. If NJDEP is confident that the reference sites were selected carefully and are expected to contain benthic communities that represent background or minimally disturbed conditions, then it makes sense to create thresholds that distinguish biological conditions that are similar to reference (unimpaired) and different from reference (impaired). The level of error associated with the identification of reference sites has immediate bearing on the percentile of the reference distribution used as a threshold. For instance, if NJDEP was certain that all of the reference sites are attaining their designated aquatic life uses, then a low reference percentile should be selected as the threshold. The 5^{th} percentile is the lowest recommended threshold possibility because the minimum (0^{th} percentile) is more susceptible to random variation caused by sampling error and natural variability and is more likely than the 5^{th} percentile to have an outlier index value.

In this data set, we described reference sites as "least disturbed", a term which recognizes the possibility that reference sites have some human activity that may affect biological integrity. Therefore, a greater degree of error in identifying reference conditions from reference sites may be acceptable for this data set. Greater error in identifying reference sites translates to selection of a threshold based on a higher reference percentile (e.g., 10^{th} or 25^{th}, see Table 9 for HGMI values associated with these percentiles). Type 1 error (labeling a site as impaired when it is actually unimpaired) is equal to the percentile value selected as a threshold.

Another alternative for threshold selection is to use the HGMI threshold values that minimize total error among reference and stressed sites in this analysis. This puts equal confidence in the selection of both reference and stressed sites. The total error rates (Type 1 and Type 2 combined) of the indices are minimized at threshold values of 44.3 and 50.2, for the $HGMI_{gen}$ and the $HGMI_{fam}$, respectively.

Threshold selection could also be coordinated to incorporate the tiers of the BCG. Narrative descriptions of the BCG tiers have meanings that can be interpreted in the context of aquatic life use protection. Sites with biological conditions indicative of tiers 1 and 2 are associated with biological integrity, without much contention. Tiers 3, 4, and 5 are associated with increasing degrees of alterations of biological integrity. NJDEP may choose to define a threshold based on the descriptions of those alterations and a professional judgment regarding the protective merits of each tier. After selecting a protective tier, HGMI values associated with the tier could be used to define a threshold (Figures 9-10 and 11-12). For assessments, the BCG tiers (Gerritsen and Leppo 2005) and the HGMI could be used in parallel to increase confidence in site assessments.

We recommend applying the HGMI in high gradient sites where samples are collected between April 1 and November 30 and processed using NJDEP protocols. Metrics must be calculated using taxa identifications at levels appropriate to the indices (genus or family), attributes defined by NJDEP, and metric adjustment and scoring formulae provided in Tables 5 and 6 of this report. Index results from samples with less than 50 or more than 200 individuals may be unreliable because metrics derived from small or large samples may be biased in ways that were not tested.

Reference sites range in size from 0.9 to 144 square kilometers, though the majority of reference sites have watersheds between 2 and 50 square kilometers. Results from test sites with catchments within these ranges are most certain. Results from sites with smaller or larger catchments should be used in assessments, though there may be an added degree of uncertainty due to extrapolation of the metric to catchment size relationships. Because the relationships use a log transformation of the catchment size, the metric adjustments for larger sites are more gradual than for smaller sites. Additional reference site data from small and large catchments should be targeted in future sampling efforts to improve our understanding of the relationships.

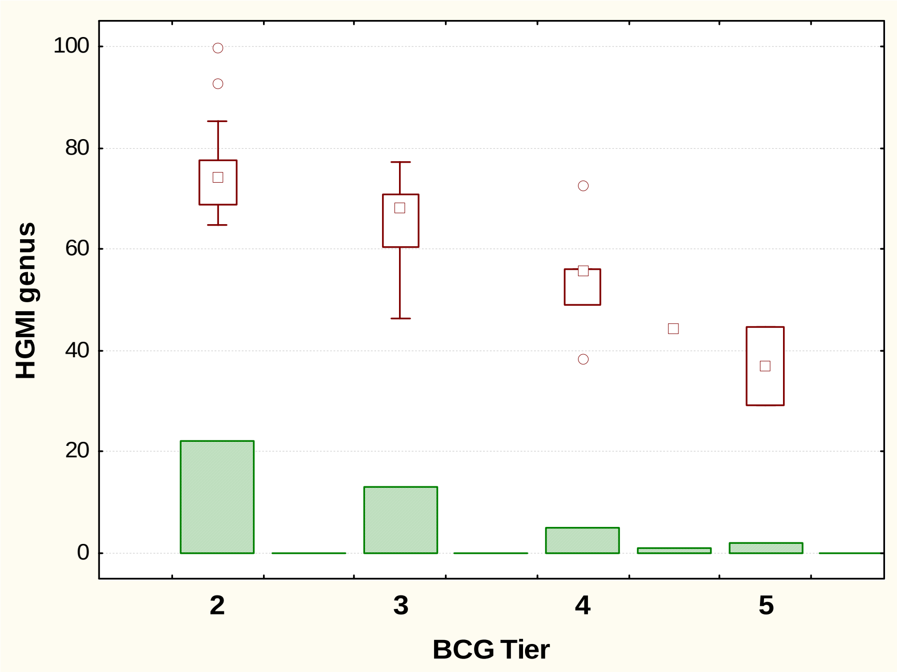

Figure 11. $HGMI_{genus}$ values and BCG tiers for reference sites, showing sample sizes in the lower histogram.

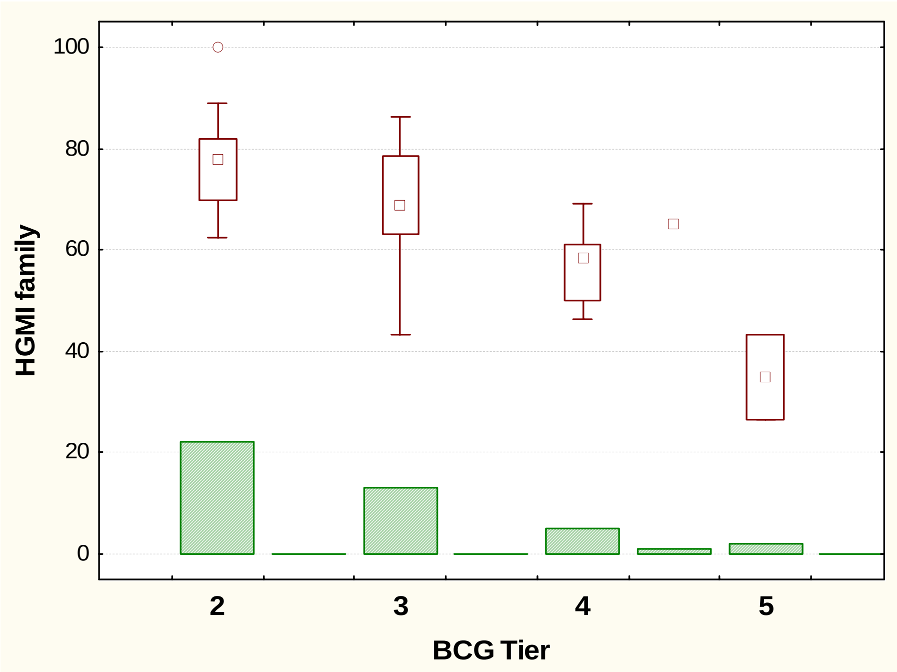

Figure 12. $HGMI_{family}$ values and BCG tiers for reference sites, showing sample sizes in the lower histogram.

We recommend that NJDEP completes the habit attributes for non-insects of the NJ taxa list. Morphology and habitat niches can be used to infer habit with reasonable certainty. These attributes are not widely published, but habits could be assigned to several taxa using state biologists' judgments and lists generated in neighboring states. This would allow testing of habit metrics in further index development and aid in sample interpretation.

NJDEP has concerns that limestone streams may represent a unique site class. Effects of geology were not examined in this report and should be the subject of further investigation. If limestone geology affects water chemistry and stream biota in the absence of human disturbance, then metric and index values in undisturbed limestone streams may not resemble reference conditions as defined by the HGMI. Application of the HGMI is recommended for limestone streams, though the uncertainty associated with an untested site classification should be communicated along with index results.

HGMI values and BCG tiers indicate that some of the reference sites have altered biological composition and functions. Such sites may have stresses that were not detected using the reference criteria. Additional criteria or more thorough review of site reference status would help refine the reference condition by eliminating biological samples with altered composition and functions. It may be possible to use data from neighboring monitoring programs to augment the reference data set.

Some systematic bias is apparently associated with the differences in sample collection protocols used by NJDEP and EPA for the headwater sites. Bias should be reduced through consistent application of protocols.

8.0 Literature Cited

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Appendix A

Reference Sites

Table A-1. Reference and degraded sites with site and watershed characteristics.

WBName	station	Ref Status	Area SqKm	Lat	Long	CollDate	CalVer	Hab Min	AgUrb 95	AgUrb 02	Sp. Cond.	DO	TempC	pH
Bear Swamp Brook	HW21	Ref	7.0	41.08	-74.22	7/7/03	c	84	1.15		39.0	7.6	20.0	6.5
Beaver Bk	AN0245	Ref	17.7	40.95	-74.46	7/12/01	c	81.5	7.35	3.48	53.5	8.2	21.5	7.7
Big Flat Bk	AN0006	Ref	74.9	41.2	-74.82	7/15/02	v	85	1.98	1.88	81.5	11.6	11.1	8.6
Camp Harmony Br of Stony Bk	AN0390	Ref	6.5	40.4	-74.8	9/9/04	c	78.5	14.33	11.39	150.5	10.1	15.2	7.8
Clove Bk	AN0309A	Ref	21.6	41.26	-74.63	6/17/98	c	93.5		17.72	174.5	10.4	14.8	8.4
Clove Brook	HW25	Ref	3.7	41.33	-74.7	7/8/03	c	86.5	0.88		223.0	7.4	18.4	7.4
Cooley Brook	HW24	Ref	4.1	41.15	-74.35	7/1/03	v	76	2.61		50.0	11.6	15.1	6.4
Criss Brook	HW20	Ref	2.7	41.23	-74.77	7/8/03	c	77	1.25		70.0	8.4	18.0	6.8
Crooked Bk	AN0252	Ref	3.4	40.94	-74.37	8/4/98	c	87.5	13.72	9.98	144.5	8.0	17.4	7.6
Dunnfield Ck	AN0012	Ref	9.6	40.97	-75.13	6/11/02	c_close	81.5	0.11	0.45	34.0	11.7	8.9	6.9
Dunnfield Creek	HW03	Ref	9.8	40.97	-75.12	7/22/03	c	87	0.34		35.4	9.1	17.5	6.9
Dwars Kill	AN0208	Ref	0.9	40.98	-73.93	7/2/03	c	84	6.80	6.81	102.5	8.2	17.2	7.8
Flat Bk	AN0007	Ref	144.4	41.16	-74.88	7/15/02	c	90	7.83	8.35	205.0	12.1	12.1	7.8
Forked Brook	HW11	Ref	3.4	41.24	-74.75	7/14/03	c	91	0.38		116.0	8.1	16.0	7.6
Franklin Pond Creek	HW27	Ref	18.3	41.1	-74.57	7/22/03	c	83	9.98		289.0	8.4	18.7	7.1
Green Brook	HW38	Ref	4.1	41.15	-74.36	7/1/03	c	86.5	1.07		117.0	5.1	17.0	6.7
Harmony Brook	HW19	Ref	5.9	40.8	-74.58	7/23/03	c	77	17.33		143.3	7.3	24.6	7.3
Hewitt Brook	HW22	Ref	2.2	41.13	-74.33	7/1/03	c	76	7.77		76.2	8.7	15.2	6.8
Hibernia Brook	HW17	Ref	5.0	40.95	-74.51	7/23/03	c	78	7.76		134.5	7.7	19.6	7.1
High Mountain Brook	HW26	Ref	5.1	41.08	-74.26	7/21/03	c	79	18.62		70.8	7.8	18.8	7.6
Jacksonburg Ck	AN0028	Ref	6.4	41.04	-74.96	7/17/01	v	81.5	5.82	4.85	62.5		8.4	7.6
Lake Lookout Bk (trib to Wawayanda Ck)	AN0294	Ref	11.1	41.19	-74.42	7/19/01	v	81	0.23		159.5	8.8	16.2	8.0
Little Flat Bk	AN0004	Ref	2.1	41.28	-74.76	7/31/01	c	93	0.29	0.49	60.5	11.6	6.9	7.8
Little Flat Bk	AN0005	Ref	9.6	41.26	-74.79	7/2/02	c	81	3.25	6.05	239.5	9.3	15.0	7.6
Lopatcong Ck	AN0051	Ref	5.3	40.74	-75.12	9/18/97	c_close	78	16.50	19.08	181.5	10.9	12.1	7.4
Lopatcong Creek	HW08	Ref	3.7	40.75	-75.11	7/30/03	c	76.5	18.52		237.4	8.5	18.3	7.5
Lubbers Run	AN0066	Ref	44.2	40.93	-74.72	8/14/01	c	83.5	18.01	16.59	274.0	8.7	19.8	7.7
Mossmans Bk	AN0260	Ref	10.1	41.11	-74.43	7/19/01	c_close	85.5	2.71	0.03	54.5	8.5	16.7	7.1
Mossmans Brook	HW07	Ref	9.6	41.11	-74.43	7/21/03	c	81.5	0.03		77.3	6.5	18.1	6.9
Musconetcong R	AN0064	Ref	62.4	40.92	-74.73	8/7/97	c	88	16.08	15.15	459.5	10.4	15.6	8.0
Parker Brook	HW10	Ref	6.8	41.24	-74.73	7/14/03	c	85.5	0.27		87.8	8.0	18.0	7.2
Pequannock River	AN0259	Ref	49.2	41.08	-74.49	8/6/98	c	90	4.79	4.40	256.5	9.6	18.5	7.8

WBName	station	Ref Status	Area SqKm	Lat	Long	CollDate	CalVer	Hab Min	AgUrb 95	AgUrb 02	Sp. Cond.	DO	TempC	pH
Primrose Bk	AN0215	Ref	1.4	40.77	-74.53	7/22/03	c	90	6.19	5.28	94.3	10.9	11.3	7.7
Rock Bk	AN0399	Ref	8.4	40.44	-74.74	6/6/02	c	80.5	6.74	7.31	140.0	10.1	14.7	7.8
Russia Bk	AN0239	Ref	29.6	41.02	-74.53	7/16/98	c	82	17.91	12.87	264.0	7.9	20.2	7.9
Shimers Bk	AN0003	Ref	17.9	41.31	-74.78	7/31/01	c	83.5	14.01	14.99	195.5	11.7	8.7	9.1
Shimmers Brook	HW14	Ref	7.3	41.3	-74.75	7/8/03	c	84	1.03		70.0	7.9	18.3	7.0
Sparta Glen Road	HW06	Ref	5.9	41.04	-74.61	7/22/03	v	77.5	14.53		251.7	7.7	18.6	7.4
Stony Brook	HW13	Ref	5.9	41.21	-74.77	7/14/03	c	87.5	0.46		55.4	6.4	18.4	6.6
Stony Brook	HW15	Ref	7.2	40.96	-75.09	7/22/03	c	78.5	7.20		52.5	8.4	19.5	7.1
Tuttles Corner Brook	HW12	Ref	9.7	41.2	-74.8	7/8/03	v	85.5	3.70		160.0	7.1	21.0	7.0
Unnamed Tributary to Westbrook	HW18	Ref	3.4	41.08	-74.34	7/20/03	v	85.5	2.15		78.7	7.0	16.3	7.5
UNT to Dead River	AN0225	Ref	1.1	40.66	-74.59	7/31/03	v	81	16.82	5.80	471.5	12.9	11.5	7.9
UNT to Troy Bk	AN0023A	Ref	24.8	41.08	-74.83	8/6/02	c	85	14.10	14.06	176.0	9.3	17.5	8.7
Van Campens Bk	AN0009	Ref	2.9	41.1	-74.93	6/12/03	c	91	1.06	1.47	36.0	10.4	8.9	6.1
Van Campens Bk	AN0011	Ref	19.4	41.06	-75	7/17/01	c	91.5	1.45	1.33	76.0	11.7	5.6	8.1
Van Campens Bk	AN0010	Ref	12.6	41.07	-74.96	7/16/02	c_close	84.5	0.40	0.43	63.0	9.0	10.4	7.8
Allendale Brook	HW29	Stress	2.5	41.02	-74.13	7/7/03	c	40	68.52		195.0	5.6	21.0	6.4
Assunpink Ck	AN0116	Stress	0.3	40.24	-74.74	6/3/03	v	61	97.91		220.0	8.8	12.9	7.2
Black Bk	AN0222	Stress	1.2	40.74	-74.42	7/24/03	v	69.5	89.55	86.67	457.0	9.7	14.7	7.3
Bound Bk	AN0424B	Stress	14.8	40.56	-74.4	6/17/04	c	41		71.91	584.0	9.6	11.6	7.6
Canoe Brook	HW30	Stress	6.8	40.79	-74.31	7/9/03	v	48.5	71.06		600.0	4.4	23.7	7.5
Deepavaal Bk	AN0271	Stress	17.0	40.89	-74.27	8/5/98	c	47.5	83.16		598.0	6.1	14.7	7.3
Demarest Brook	HW32	Stress	2.8	40.95	-73.96	7/16/03	c	49.5	71.90		486.6	7.7	16.7	7.5
Diamond Bk	AN0278	Stress	7.1	40.95	-74.14	8/11/98	v	59.5	95.47	95.18	528.0	7.3	18.4	7.2
East Branch of Rahway River	HW33	Stress	10.4	40.74	-74.27	7/29/03	c	52.5	92.15		782.0	5.4	18.6	7.0
Elizabeth River	AN0204	Stress	41.8	40.68	-74.23	9/16/98	c	46	93.40	93.31	696.0	8.2	17.1	7.4
Goffle Bk	AN0277	Stress	22.6	40.94	-74.16	8/11/98	c	60	87.53	86.44	421.5	6.2	15.9	7.6
Goffle Bk	AN0277A	Stress	10.7	40.98	-74.14	7/1/04	c_close	42.5		88.56	676.5	5.7	21.0	7.1
Goffle Brook	HW37	Stress	10.6	40.98	-74.14	7/7/03	c	59	88.51		771.0	6.9	25.0	7.4
Gold Run	AN0107	Stress	5.3	40.24	-74.82	7/1/97	c	72.5	87.63	81.52	319.5	9.1	16.8	7.9
Hirshfeld Brook	HW41	Stress	9.3	40.94	-74.01	7/16/03	c	53	96.64		720.0	4.9	22.0	7.5
Hohokus Bk	AN0288	Stress	47.5	40.97	-74.11	8/18/98	v	59.5	81.56	77.39	626.0	8.6	18.1	7.4
Loantaka Bk	AN0220	Stress	3.4	40.77	-74.46	7/24/03	c	62	88.69	85.97	863.0	9.6	16.4	7.6
Lockatong Ck	AN0086	Stress	3.8	40.53	-74.95	7/15/97	c	74.5	88.17	65.60	163.0	8.9	19.3	7.4

WBName	station	Ref Status	Area SqKm	Lat	Long	CollDate	CalVer	Hab Min	AgUrb 95	AgUrb 02	Sp. Cond.	DO	TempC	pH
Mile Run	AN0429	Stress	14.8	40.51	-74.47	6/17/04	c	63	94.23	90.74	417.5	8.0	19.7	7.5
Mill Bk	AN0436	Stress	10.3	40.51	-74.38	7/8/04	c_close	75.5	92.45	89.27	588.5	9.2	21.3	7.5
Mill Brook	HW42	Stress	8.9	40.5	-74.38	7/31/03	v	51.5	89.27		669.0	8.3	19.0	7.3
Morses Creek	HW43	Stress	6.1	40.65	-74.27	7/2/03	c	39	91.99		704.0	6.8	20.0	7.3
Musquapsink Bk	AN0206	Stress	18.1	40.99	-74.02	7/1/03	c	52	86.79	83.62	570.0	7.5	19.7	7.4
Naachtpunkt Brook	HW45	Stress	3.6	40.91	-74.24	7/9/03	c	43	65.10		690.0	6.8	21.0	7.4
Nomehegan Brook	HW46	Stress	7.5	40.68	-74.33	7/2/03	c	44.5	74.78		401.0	7.3	24.0	7.2
Overpeck	HW47	Stress	14.0	40.88	-73.99	7/16/03	c	34.5	90.96		771.0	5.9	18.9	7.5
Overpeck Ck	AN0212	Stress	5.3	40.91	-73.97	7/2/03	c	51.5		82.07	483.0	9.1	18.3	7.6
Packanack Bk	AN0270	Stress	2.5	40.93	-74.25	8/5/98	c	62	82.39	79.26	281.5	8.6	22.3	8.4
Papakating Ck	AN0307	Stress	96.8	41.19	-74.62	6/10/98	c	45	44.79	42.13	327.5	9.1	15.5	7.7
Pascack Bk	AN0207	Stress	73.4	40.99	-74.02	7/1/03	v	71.5	88.06		519.5	8.4	20.1	7.3
Rahway River	AN0192	Stress	10.2	40.77	-74.28	10/13/04	c	42.5	84.28	75.11	1234.5	12.2	6.6	7.3
Rahway River	AN0194	Stress	80.7	40.67	-74.31	10/13/04	c	58	86.23	76.01	716.5	11.0	7.7	7.4
Rahway River	AN0195	Stress	107.4	40.62	-74.28	10/21/04	c_close	56	83.48	79.15	519.0	11.3	8.4	7.9
Rahway River	HW51	Stress	10.3	40.77	-74.28	7/19/03	v	45	75.08		1270.0	8.4	23.0	7.6
Ramapo River	AN0267	Stress	0.2	41.04	-74.24	8/7/98	c	72.5	89.29		411.0	10.9	17.7	7.8
Robinsons Br	AN0199	Stress	52.8	40.61	-74.29	10/21/04	v	57	81.36	78.54	266.0	11.7	8.6	7.6
Royce Bk Br	AN0412	Stress	5.2	40.51	-74.63	9/30/04	v	68	87.73	76.00	238.0	9.0	13.5	7.6
Saddle R	AN0279	Stress	15.7	41.07	-74.09	7/8/03	c	73.5	94.36		608.0	8.4	19.8	7.9
Saddle R	AN0282	Stress	58.9	40.97	-74.09	8/14/98	c	76	86.87		416.0	10.2	16.9	7.8
Sawmill Bk	AN0435	Stress	9.7	40.46	-74.43	7/29/04	c	38	87.76	83.19	398.5	7.2	20.4	6.8
Second River	AN0293	Stress	27.9	40.78	-74.15	6/24/04	c	43.5		91.79	719.0	8.9	19.8	7.7
Second River	HW52	Stress	5.7	40.81	-74.21	7/19/03	c	53	96.67		782.0	8.6	18.3	7.6
South Br Rahway River	AN0200	Stress	2.5	40.55	-74.34	10/7/04	c	56.5	88.01	77.49	416.0	10.3	12.8	7.8
South Br Rahway River	AN0201	Stress	22.9	40.58	-74.3	6/12/02	c	53.5	91.04	84.78	660.5	10.5	9.9	7.0
Tenakill Bk	AN0209	Stress	22.7	40.98	-73.97	7/1/03	c	55.5	87.74	84.94	536.5	7.0	20.8	7.3
Third River	AN0292	Stress	32.1	40.83	-74.14	8/19/98	c	42.5	93.47	90.83	468.5	9.1	15.5	7.4
Third River	AN0292A	Stress	13.1	40.83	-74.18	9/25/98	c	50.5		83.85	453.0	8.2	13.6	7.3
Third River	HW53	Stress	13.4	40.83	-74.18	7/17/03	c	55	84.05		690.0	8.4	16.0	7.7
Unnamed Tributary to Passaic River	HW54	Stress	8.3	40.7	-74.41	7/28/03	c	36.5	91.64		550.0	12.5	26.1	8.7
UNT to Robinsons Br	AN0197	Stress	5.2	40.63	-74.35	10/7/04	c	62.5	95.46	92.26	456.5	11.1	8.8	7.7
UNT to Robinsons Br	AN0198	Stress	4.4	40.62	-74.33	10/7/04	c	55.5	91.32	90.18	473.0	11.4	7.7	7.6
UNT to Shipetaukin Ck	AN0110	Stress	0.6	40.32	-74.73	6/3/03	c	73.5	85.00	49.27	221.0	10.1	10.9	7.3

WBName	station	Ref Status	Area SqKm	Lat	Long	CollDate	CalVer	Hab Min	AgUrb 95	AgUrb 02	Sp. Cond.	DO	TempC	pH
Valentine Bk	AN0284	Stress	6.7	41.03	-74.15	7/30/03	c	46.5	83.88	78.92	847.0	7.6	19.2	7.5
Van Saun Bk	AN0211	Stress	15.5	40.91	-74.04	7/8/03	c	56.5	92.89	91.81	729.5	5.5	22.9	7.8
W Br Saddle River	AN0280	Stress	4.8	41.07	-74.1	7/8/03	c	53	93.36	85.41	648.5	8.4	21.7	7.9
West Br Elizabeth River	AN0202	Stress	7.9	40.69	-74.24	9/16/98	c_close	37.5	83.40	83.50	484.0	7.3	24.1	7.5
West Branch Elizabeth River	HW55	Stress	7.4	40.69	-74.25	7/2/03	c	53	83.07		613.0	4.4	21.3	7.0
West Branch of Shabakunk Creek	HW56	Stress	6.3	40.26	-74.78	7/29/03	v	52.5	83.43		330.6	7.4	22.3	7.4

Appendix B

Metric Statistics

Trend: Direction of metric response with increasing stress. The trends for unresponsive metrics were left blank.

Incr = increasing metric values with increasing stress.

Decr = decreasing metric values with increasing stress.

DE: Discrimination Efficiency = the percentage of degraded samples lower or higher than the quartile of the reference samples, in the direction of the trend (calibration data only).

$CV_{ref:}$ Coefficient of Variability = the standard deviation of reference metric values over the mean of the values, expressed as a percentage.

Table B-1. Performance statistics for metrics tested in New Jersey high gradient streams.

Metric Name	Metric Code	Trend	DE	CV_{ref}
Richness				
Total Taxa	TotalTax	Decr	90.7	23.1
adj Total Taxa	adjTotalTax	Decr	79.1	21.8
Total Taxa @ family	TotalFam	Decr	93.0	21.0
EPT Taxa @ family	EPTFam	Decr	95.3	29.7
Insect Taxa	InsectTax	Decr	93.0	24.0
Insect Taxa @ family	InsectFam	Decr	97.7	23.7
Non-Insect Taxa Percent	NonInsPT	Incr	90.7	62.0
Non-Insect Taxa Percent @ family	NonInsFamPT	Incr	95.3	59.9
EPT Taxa	EPTTax	Decr	97.7	32.5
Ephemeroptera Taxa	EphemTax	Decr	90.7	62.5
adj Ephemeroptera Taxa	adjEphemTax	Decr	90.7	56.3
Ephemeroptera Taxa @ family	EphemFam	Decr	93.0	50.4
adj Ephemeroptera Taxa @ family	adjEphemFam	Decr	93.0	46.5
Plecoptera Taxa	PlecoTax	Decr	100.0	52.2
Plecoptera Taxa @ family	PlecoFam	Decr	100.0	56.0
adj Plecoptera Taxa @ family	adjPlecoFam	Decr	97.7	51.0
Trichoptera Taxa	TrichTax	Decr	86.0	38.5
Trichoptera Taxa @ family	TrichFam	Decr	88.4	38.0
Diptera Taxa	DipTax		30.2	35.3
Midge Taxa	ChiroTax		30.2	37.9
Orthocladiinae Taxa	OrthoTax		32.6	69.7
Tanytarsini Taxa	TanytTax		18.6	67.2
Coleoptera Taxa	ColeoTax	Decr	76.7	54.3
Crustacea & Mollusca Taxa	CrMolTax	Incr	51.2	115.8
adj Crustacea & Mollusca Taxa	adjCrMolTax	Incr	67.4	105.4
Oligochaeta Taxa	OligoTax	Incr	76.7	57.4
Composition				
% EPT	EPTPct	Decr	76.7	40.1
% EPT excluding Hydropsychidae	EPTnHPct	Decr	90.7	50.5
adj % EPT excluding Hydropsychidae	adjEPTnHPct	Decr	93.0	47.9
% EPT excl. Hydropsychidae, include Diplectrona	sEPTpct	Decr	90.7	49.6
adj % EPT excl. Hydropsychidae, inc. Diplectrona	adjsEPTpct	Decr	93.0	46.2
% EPT excluding Hydropsychidae and Baetidae	EPTnHBPct	Decr	100.0	55.0
adj % EPT excl. Hydropsychidae and Baetidae	adjEPTnHBPct	Decr	100.0	51.9
% Ephemeroptera	EphemPct	Decr	72.1	87.3
% Plecoptera	PlecoPct	Decr	100.0	115.2
% Trichoptera	TrichPct	Decr	67.4	58.9
% Odonata	OdonPct		9.3	144.3
% Coleoptera	ColeoPct	Decr	74.4	102.6
% Diptera	DipPct		39.5	56.4
% Midge	ChiroPct		32.6	64.4
Cricotopus&Chironomus/Chironomidae	CrCh2ChiPct	Incr	55.8	245.1
adj Cricotopus&Chironomus/Chironomidae	adjCrCh2ChiPct		23.3	989.1
% Orthocladiinae:Midges	Orth2ChiPct		37.2	78.0
% Tanytarsini	TanytPct		27.9	92.1
% Tanytarsini:Midges	Tnyt2ChiPct		23.3	77.8
% Non-Insect	NonInPct	Incr	74.4	118.9

Metric Name	Metric Code	Trend	DE	CV_{ref}
% Amphipoda	AmphPct	Incr	53.5	285.8
% Isopoda	IsoPct	Incr	51.2	404.7
% Crustacea & Mollusca	CrMolPct	Incr	65.1	195.2
% Gastropoda	GastrPct	Incr	58.1	329.8
% Bivalvia	BivalPct		32.6	413.5
% Oligochaeta	OligoPct		44.2	106.1
% Tubificidae	TubifPct	Incr	62.8	340.8
% Hydropsychidae:EPT	Hyd2EPTPct		44.2	80.2
% Baetidae:Ephemeroptera	Baet2EphPct	Decr	53.5	82.8
% Hydropsychidae:Trichoptera	Hyd2TriPct	Incr	53.5	63.6
Evenness				
Shannon-Weiner Index (base e)	Shan_e	Decr	81.4	14.1
Evenness	Evenness	Decr	83.7	14.7
Margoleff's Diversity	D_Mg	Decr	90.7	23.7
adj Margoleff's Diversity	adjD_Mg	Decr	81.4	22.5
Simpson's Index	D	Incr	62.8	57.1
% dominant 1	Dom01Pct		46.5	43.7
% dominant 1 @ family	Dom1Fam	Incr	55.8	37.1
FeedingGroup				
% Collector	CllctPct	Incr	72.1	49.5
% Filterer	FiltrPct		46.5	51.8
% Predator	PredPct	Decr	58.1	61.1
% Scraper	ScrapPct	Decr	67.4	71.6
% Scraper @ family	ScrapFamPct	Decr	83.7	61.4
% Shredder	ShredPct		37.2	74.5
Collector Taxa	CllctTax		18.6	33.6
adj Collector Taxa	adjCllctTax		32.6	31.6
Filterer Taxa	FiltrTax		25.6	40.4
Predator Taxa	PredTax	Decr	62.8	42.6
Scraper Taxa	ScrapTax	Decr	81.4	50.8
adj Scraper Taxa	adjScrapTax	Decr	81.4	48.4
Scraper Taxa @ family	ScrapFam	Decr	81.4	34.2
Shredder Taxa	ShredTax		48.8	34.0
Tolerance				
Beck's Index	BeckBI	Decr	100.0	36.3
Hilsenhoff's Index	HBI	Incr	95.3	24.8
adj Hilsenhoff's Index	adjHBI	Incr	95.3	22.4
Hilsenhoff's Index @ family	HBI_Fam	Incr	88.4	20.8
adj Hilsenhoff's Index @ family	adjHBI_Fam	Incr	90.7	19.5
Biotic Index (BCG taxa)	BCGTaxaBI	Incr	100.0	10.4
adj Biotic Index (BCG taxa)	adj BCGTaxaBI	Incr	100.0	9.9
Biotic Index (BCG individuals)	BCGBI	Incr	95.3	13.3
adj Biotic Index (BCG individuals)	adjBCGBI	Incr	95.3	11.7
% Intolerant	IntolPct	Decr	100.0	53.7
adj % Intolerant	adjIntolPct	Decr	100.0	51.2
% Tolerant	TolerPct	Incr	58.1	93.1
adj % Tolerant	adjTolerPct	Incr	58.1	84.6
Intolerant Taxa	IntolTax	Decr	100.0	38.4
Tolerant Taxa	TolerTax	Incr	58.1	72.3

Metric Name	Metric Code	Trend	DE	CV_{ref}
adj Tolerant Taxa	adjTolerTax	Incr	74.4	67.2
BCG				
BCG attr 2 taxa	Att2Taxa	Decr	100.0	52.7
BCG attr 3 taxa	Att3Taxa	Decr	97.7	43.9
BCG attr 2&3 taxa	Att23Taxa	Decr	100.0	34.9
BCG attr 4 taxa	Att4Taxa		34.9	40.2
adjBCG attr 4 taxa	adjAtt4Taxa		44.2	36.4
BCG attr 5 taxa	Att5Taxa	Incr	72.1	52.9
% BCG attr 2	Att2Pct	Decr	97.7	70.1
adj % BCG attr 2	adjAtt2Pct	Decr	97.7	64.1
% BCG attr 3	Att3Pct	Decr	83.7	66.5
% BCG attr 4	Att4Pct		41.9	50.3
adj % BCG attr 4	adjAtt4Pct	Incr	55.8	47.5
% BCG attr 5	Att5Pct	Incr	62.8	64.1
Habit				
% Burrower	BrrwrPct		37.2	94.2
% Climber	ClmbrPct		34.9	74.9
% Clinger	ClngrPct	Decr	79.1	28.7
% Sprawler	SprwlPct	Decr	69.8	62.9
adj % Sprawler	adjSprwlPct	Decr	69.8	57.9
% Swimmer	SwmmrPct	Decr	62.8	136.6
Burrower Taxa	BrrwrTax		9.3	79.9
Climber Taxa	ClmbrTax		46.5	34.5
Clinger Taxa	ClngrTax	Decr	93.0	28.5
adj Clinger Taxa	adjClngrTax	Decr	95.3	26.4
Sprawler Taxa	SprwlTax	Decr	60.5	43.4
Swimmer Taxa	SwmmrTax		44.2	63.7
adj Swimmer Taxa	adjSwmmrTax	Decr	83.7	58.5
% Clinger @ family	ClngrFamPct	Decr	79.1	34.0

Appendix C

Selected Metric Distributions

Refer to Appendix B for metric code translation.

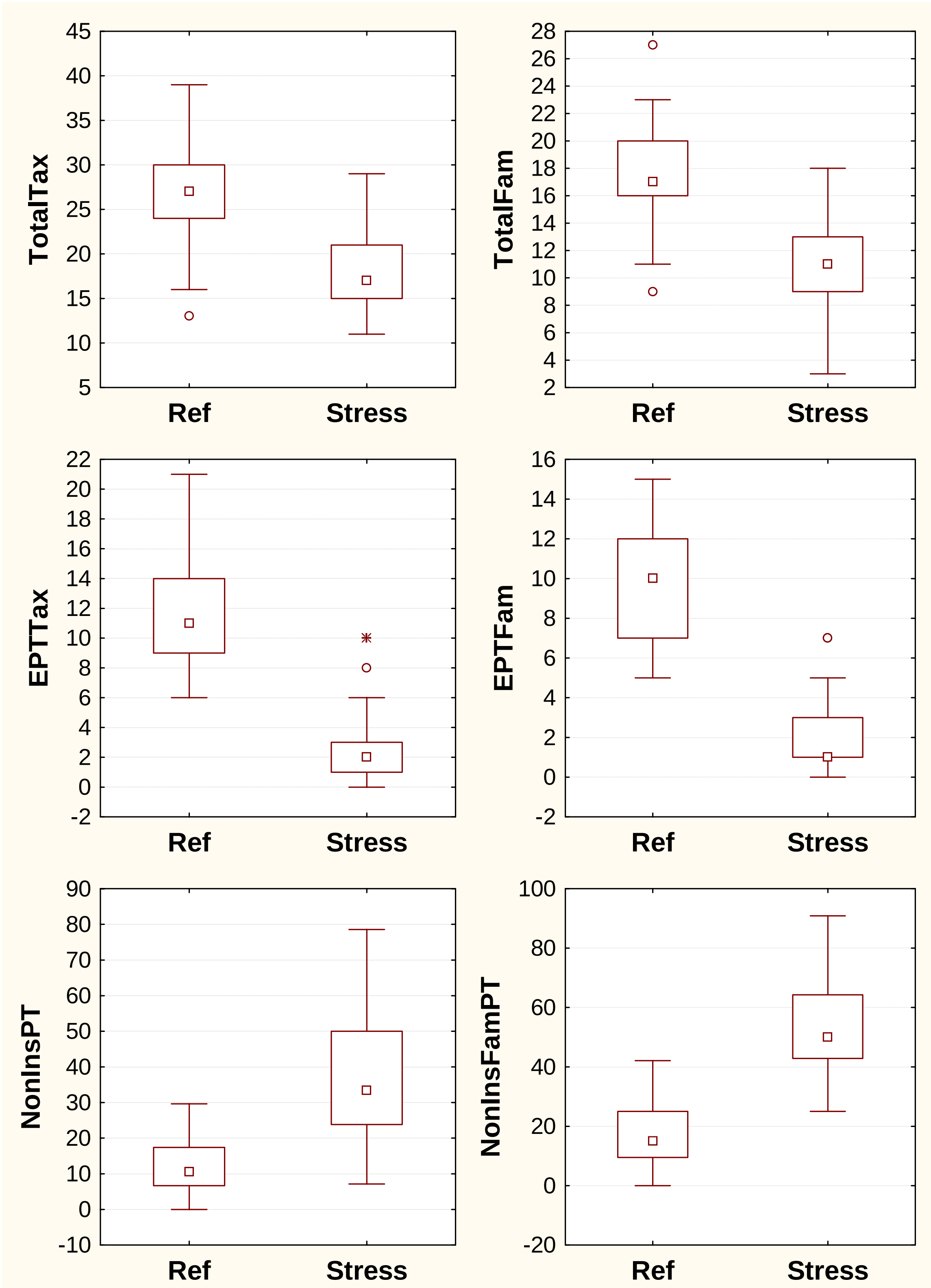

Figure C-1. Metric distributions in calibration reference and degraded (stress) sites.

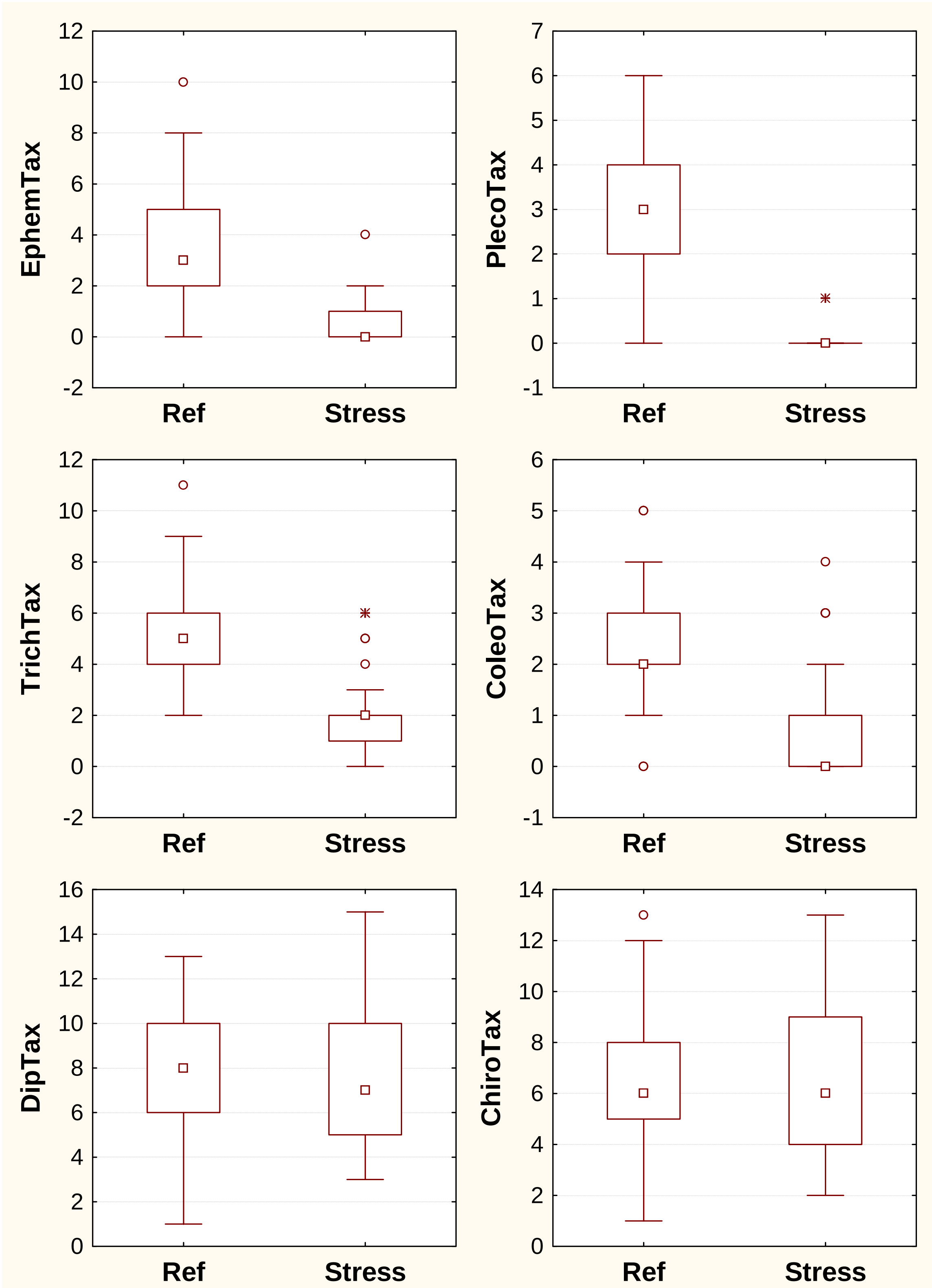

Figure C-2. Metric distributions in calibration reference and degraded (stress) sites.

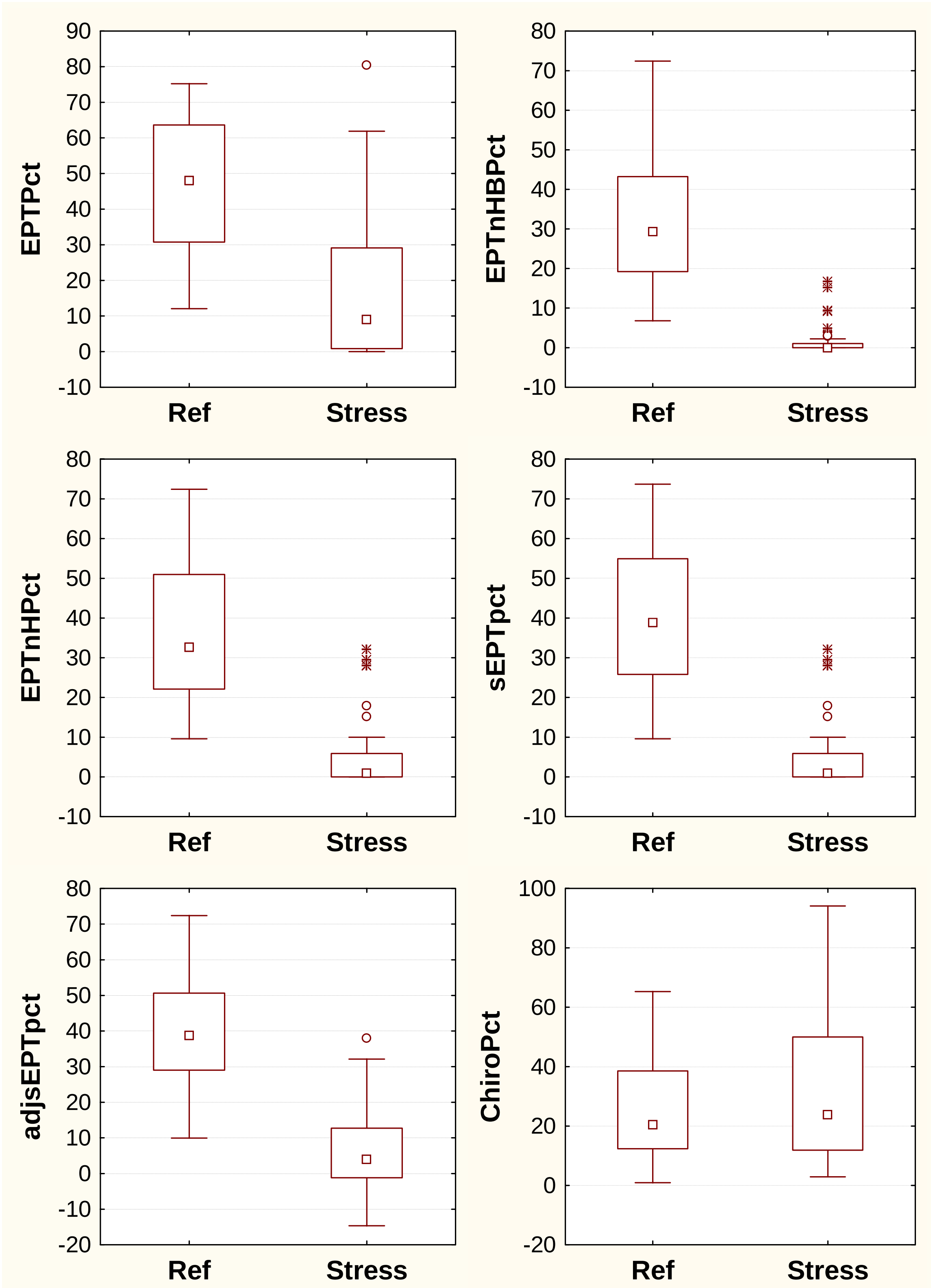

Figure C-3. Metric distributions in calibration reference and degraded (stress) sites.

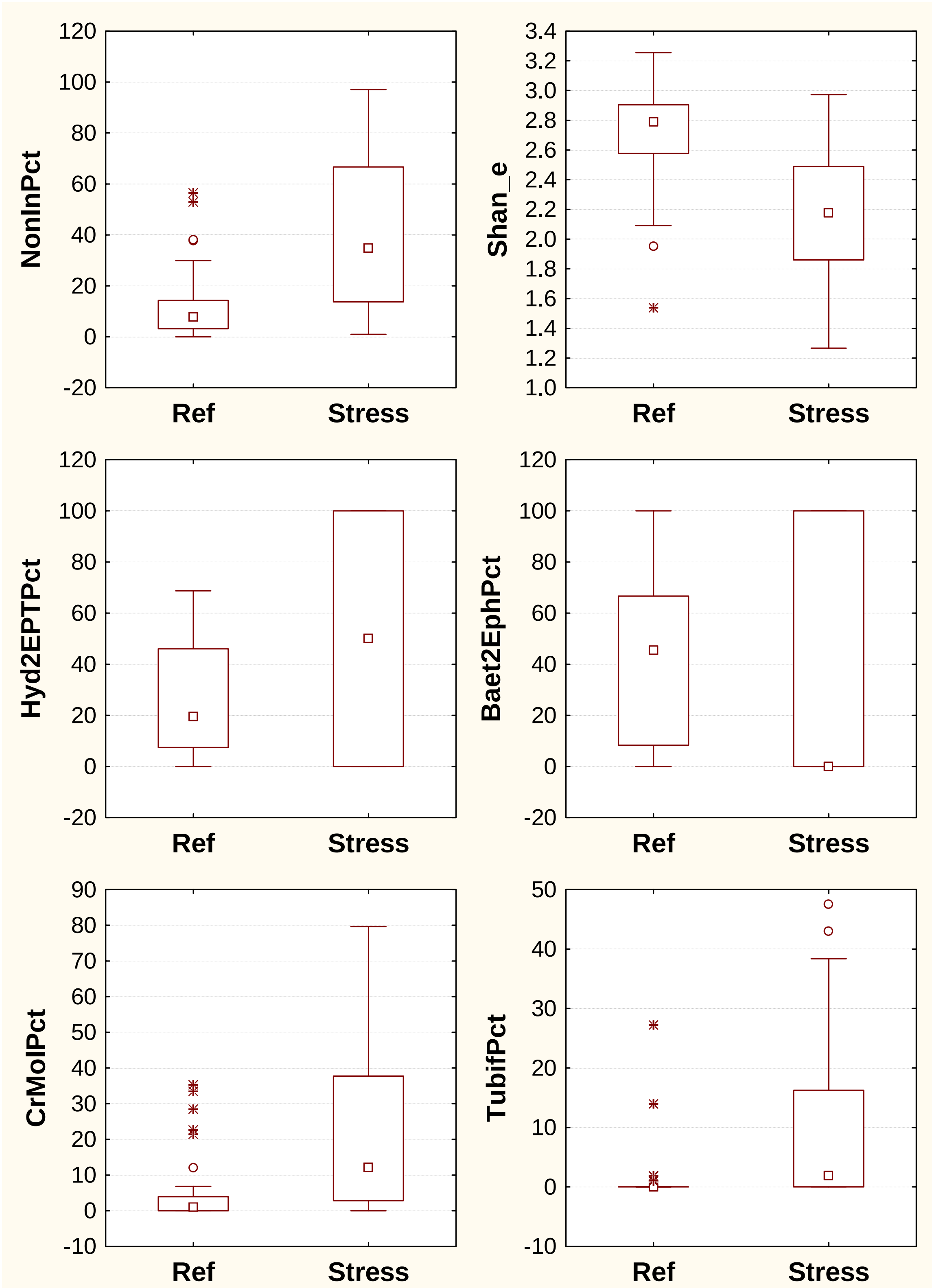

Figure C-4. Metric distributions in calibration reference and degraded (stress) sites.

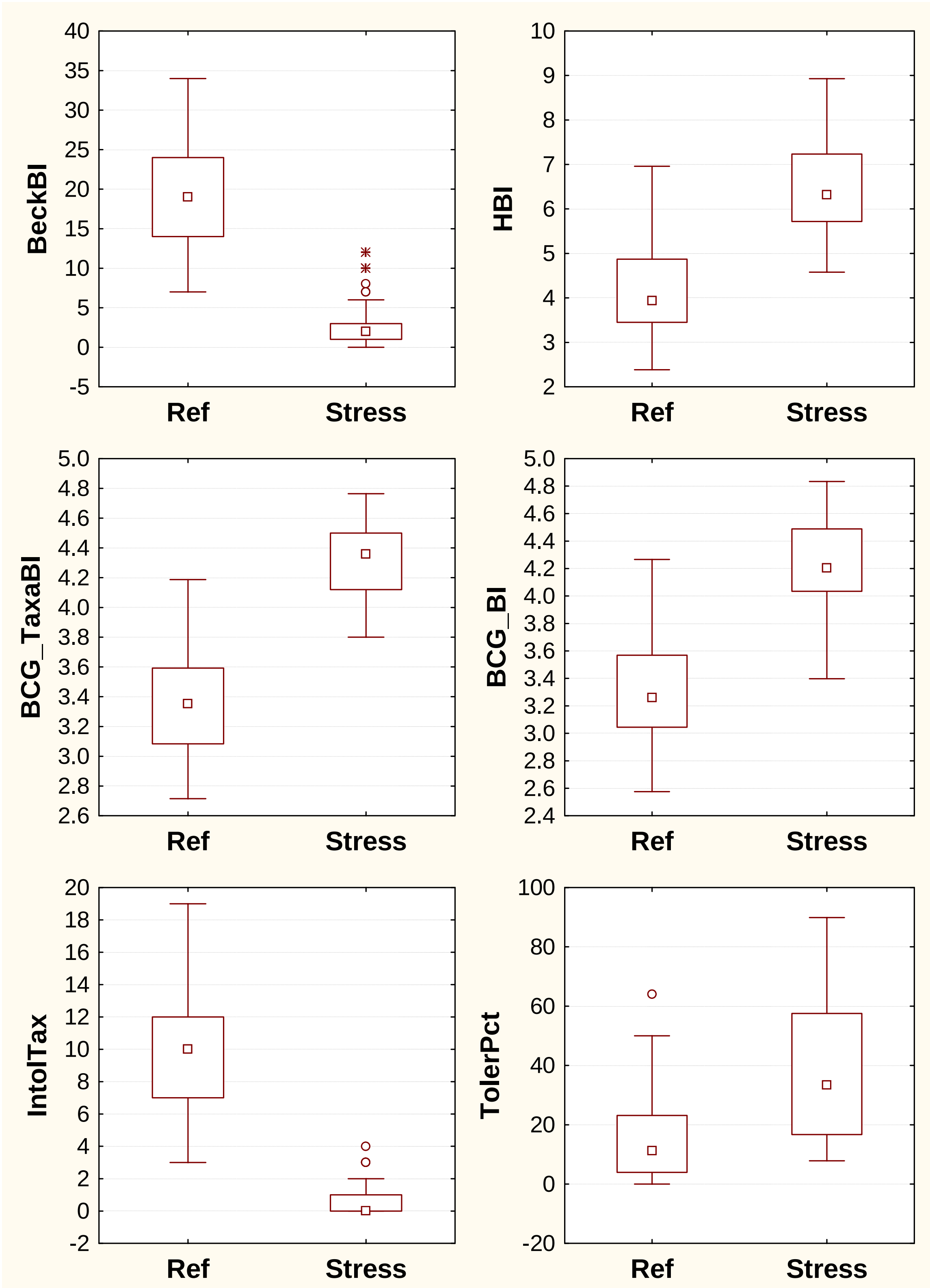

Figure C-5. Metric distributions in calibration reference and degraded (stress) sites.

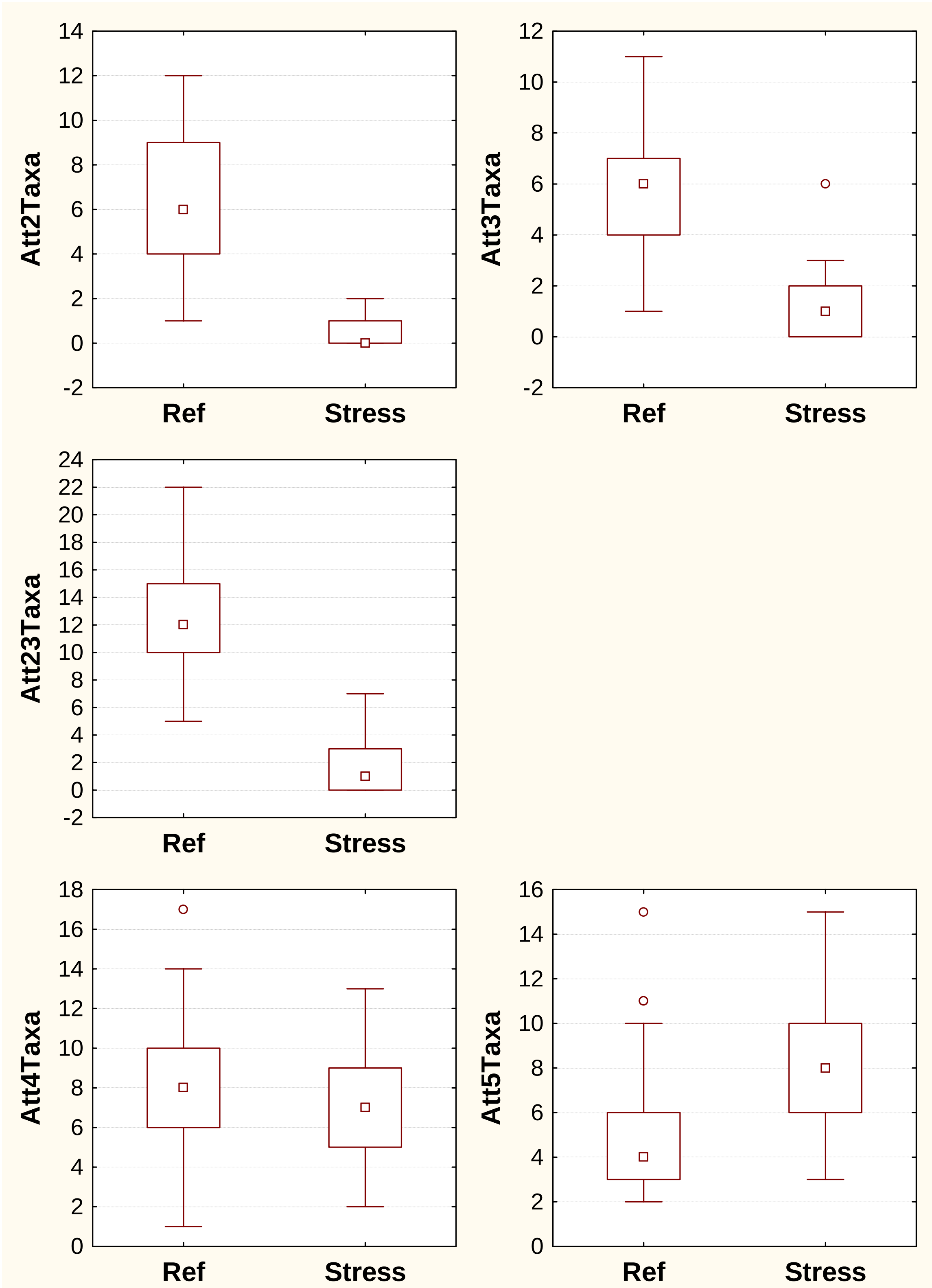

Figure C-6. Metric distributions in calibration reference and degraded (stress) sites.

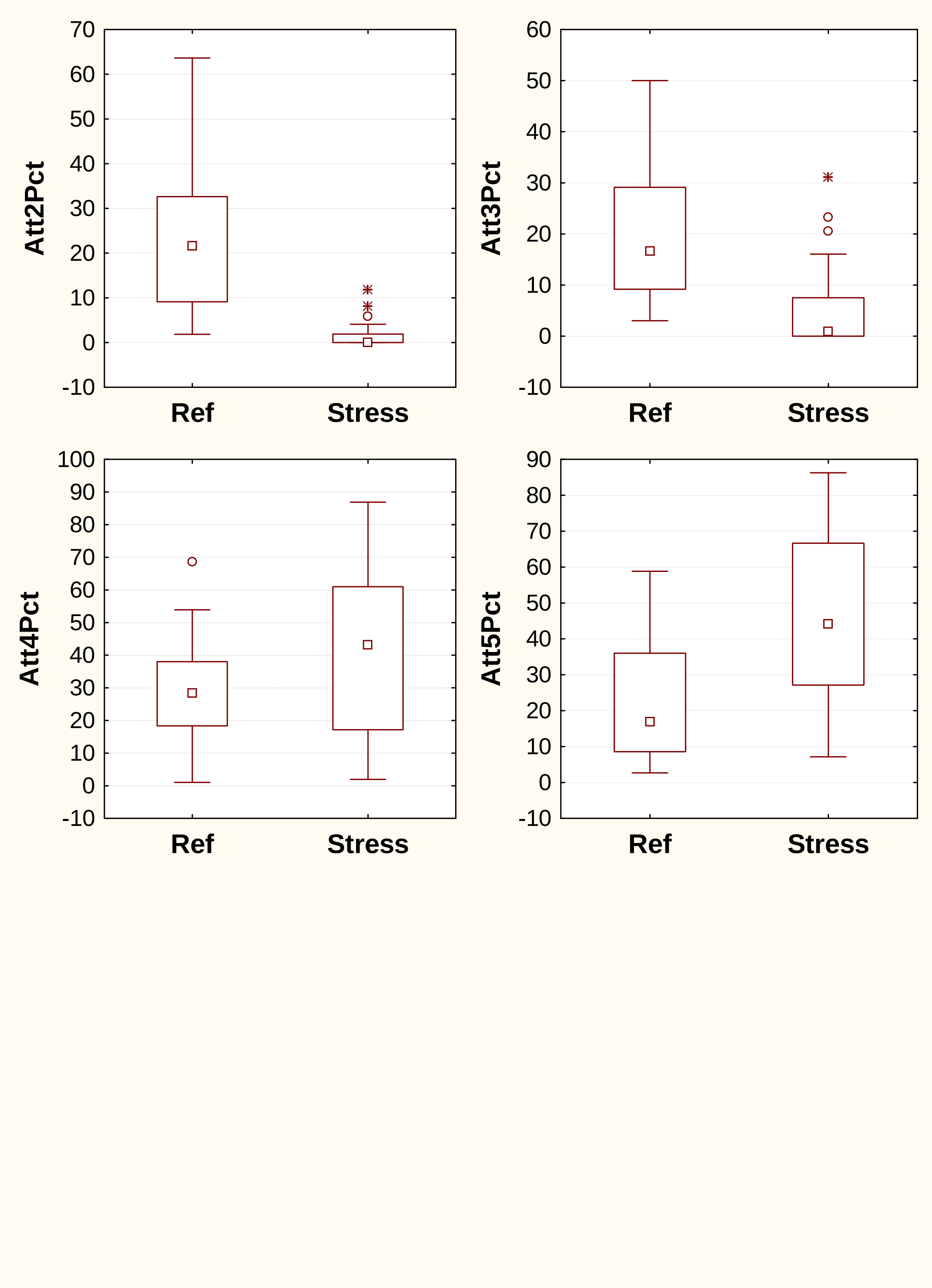

Figure C-7. Metric distributions in calibration reference and degraded (stress) sites.

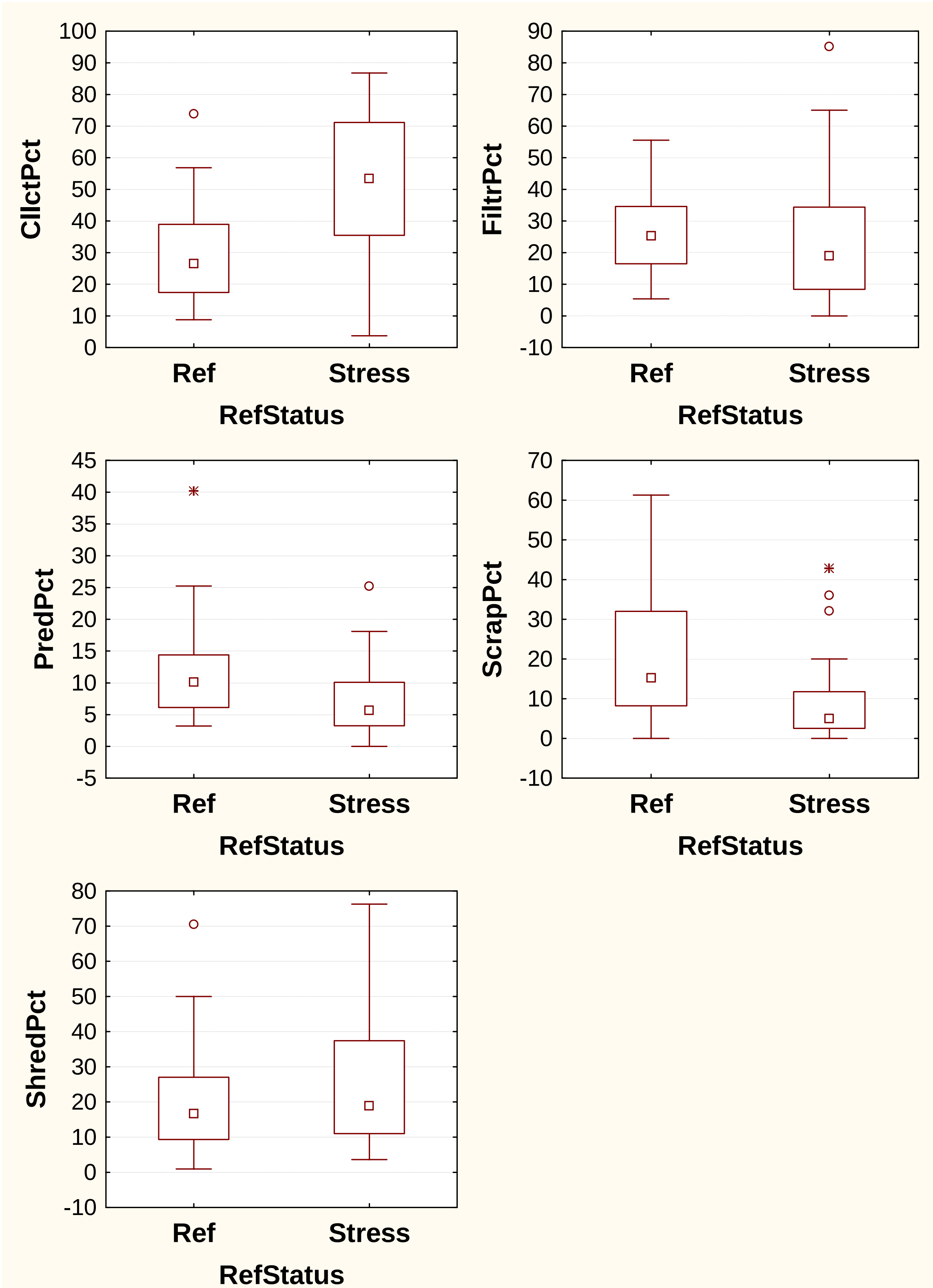

Figure C-8. Metric distributions in calibration reference and degraded (stress) sites.

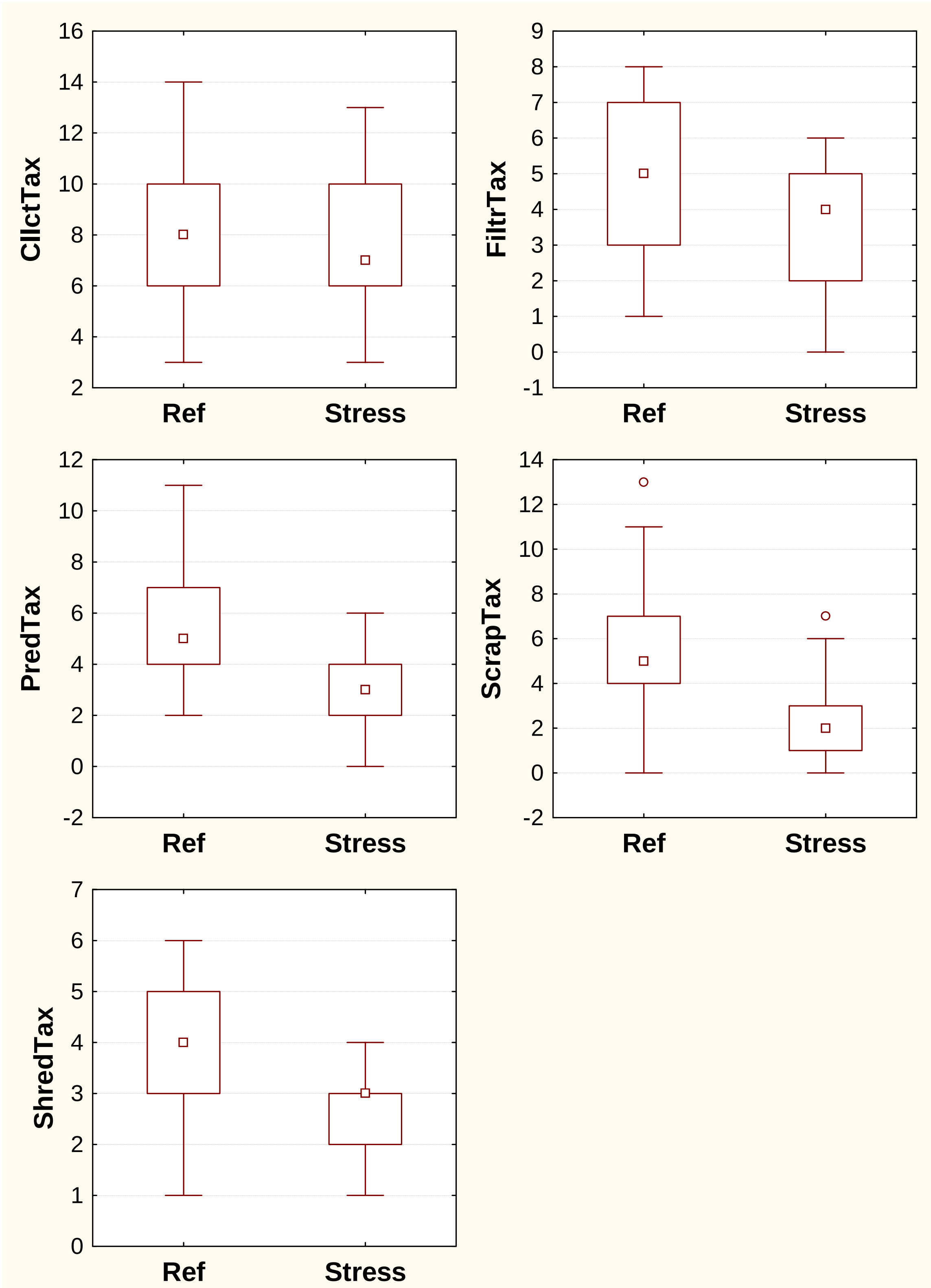

Figure C-9. Metric distributions in calibration reference and degraded (stress) sites.

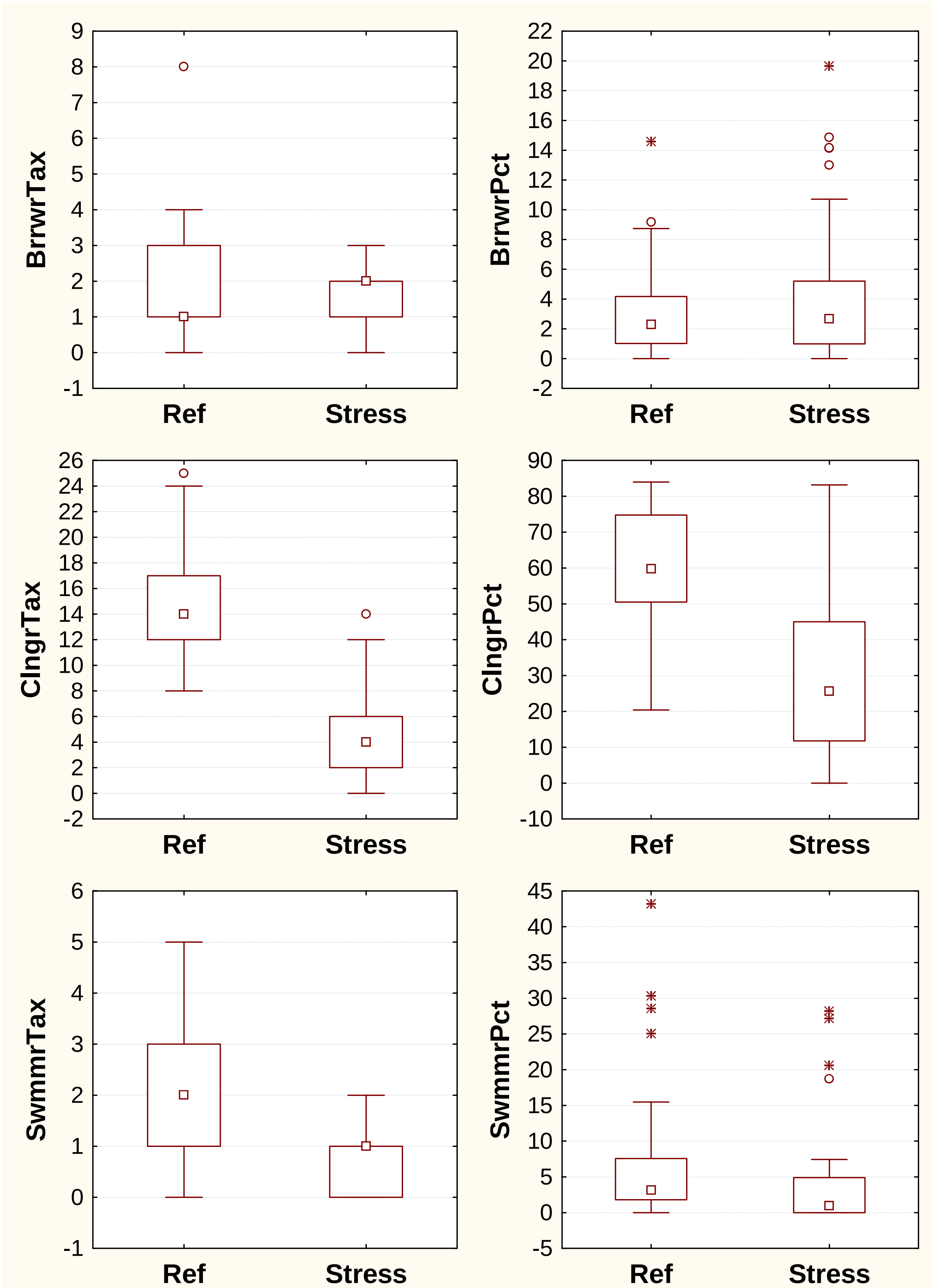

Figure C-10. Metric distributions in calibration reference and degraded (stress) sites.

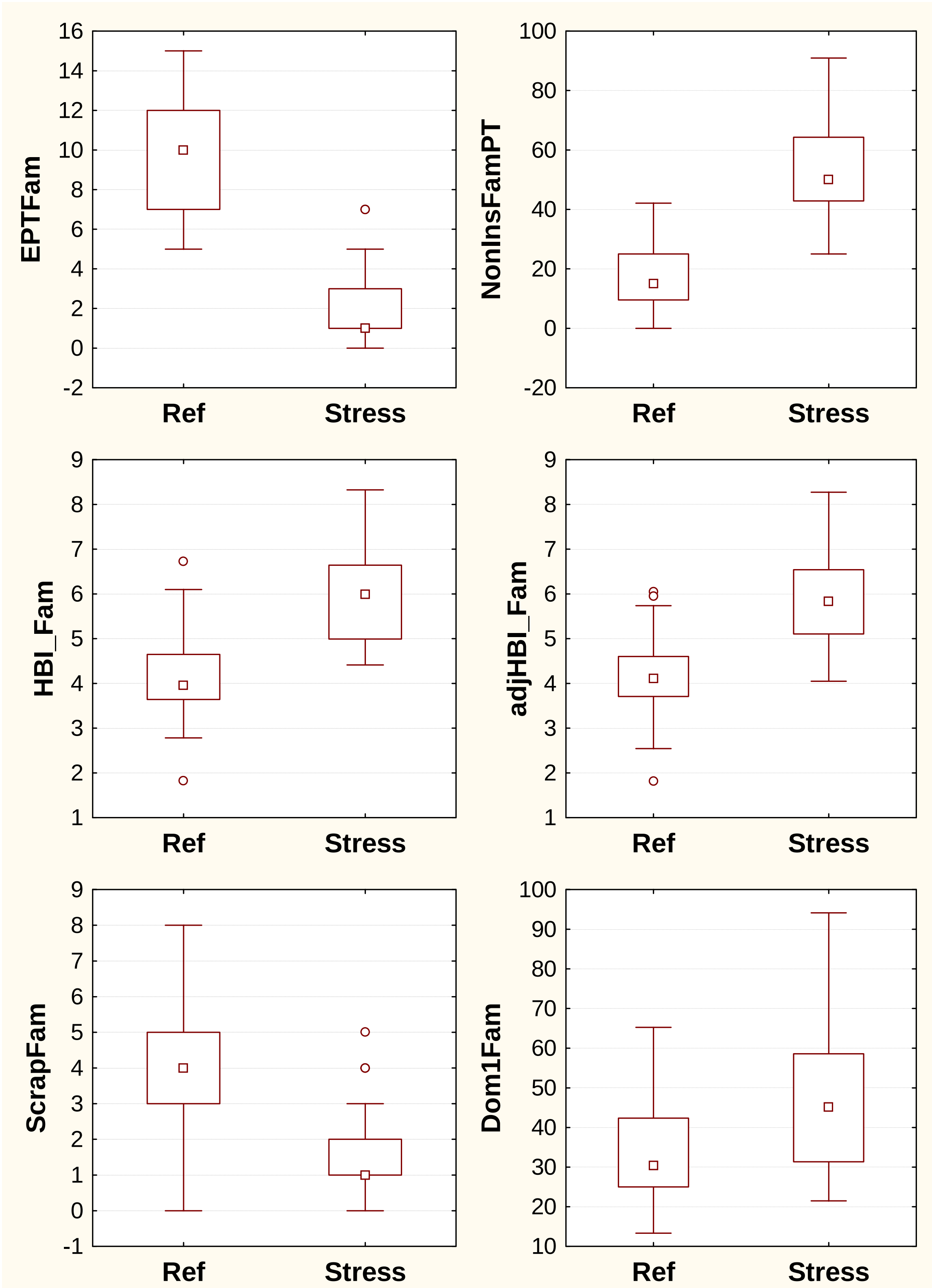

Figure C-11. Metric distributions in calibration reference and degraded (stress) sites.

Appendix D

Index Alternatives

The following tables describe the various compilations of metrics that were tested to find an index that discriminates between reference and degraded sites, that contains non-redundant metrics from several metric categories, and that is precise. In each column, the metrics with numbers in the cells are included in the that index alternative, which is summarized in the performance statistics at the bottom of the table. Refer to Appendix B for translations of the metric codes.

The first index is the NJIS and the four following indices (NJa – NJd) are variations on the NJIS. Indices 1 – 41 are alternatives that were attempted because the metric combinations were promising in this data set.

Index 41 is the genus index recommended in the report. Index 21 is the recommended family index. Indices 2 and 3 contain redundant metrics. Index 8adj was adjusted for catchment area at the index level (individual metrics were not adjusted).

Table D-1. Index alternatives and performance statistics.

Metric Code	NJIS	NJ a	NJ b	NJ c	NJ d	1	2	3	4	5	6	7	8	8 adj
TotalTax		a			d									
NonInsPT						1	2	3	4	5	6	7		
EPTTax		a			d	1	2	3			6			
EPTPct	NJ	a	b								6	7		
EPTnHPct				c	d	1	2	3	4	5			8	8
Shan_e					d			3						
ScrapTax						1	2	3	4			7		
BeckBI							2	3						
HBI		a			d	1			4		6			
Dom01Pct		a												
Att23Taxa									4					
TotalFam	NJ		b	c										
NonInsFamPT													8	8
EPTFam	NJ		b	c						5		7	8	8
ScrapFam													8	8
HBI_Fam	NJ		b	c						5		7	8	8
Dom1Fam	NJ		b	c										
Ref 75th %ile	30	82	83	82	84	80	80	83	79	85	84	80	82	79
Ref 25th %ile	27	65	63	63	65	63	59	66	63	63	64	66	64	62
Ref Quartile Range	3	17	21	19	19	18	21	17	16	22	20	14	17	17
Calibration DE	93	98	93	95	98	100	100	100	100	100	98	100	100	100
Ref Median	30	76	75	73	77	71	71	74	73	79	77	73	74	70
Stress Median	12	32	29	28	35	22	19	27	21	23	28	26	19	15
Quartile Z-score	6	2.6	2.2	2.3	2.3	2.8	2.4	2.7	3.2	2.6	2.5	3.4	3.1	3.3
Mann-Whitney Z	6.6	7.1	6.9	7.1	7.2	7.3	7.4	7.3	7.4	7.3	7.1	7.3	7.4	7.4
Verif. Stress <refcal25	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Verif. Ref >refcal25	38	75	75	50	75	50	63	63	50	63	63	63	63	50

Table D-2. Index alternatives and performance statistics.

Metric Code	9	10	11	12	13	14	15	16	17	18	19	20	**21**
NonInsPT							15	16		18	19		
EphemTax										18	19		
PlecoTax										18	19		
TrichTax										18	19		
EPTnHPct	9				13	14			17	18	19	20	
adjEPTnHPct													21
EPTnHBPct		10	11	12			15	16					
ScrapPct										18			
ScrapTax							15	16			19		
ClngrPct										18			
ClngrTax								16			19		
HBI							15	16					
TALUTaxaBI										18	19		
Att23Taxa							15	16					
TotalFam									17				
NonInsFamPT	9	10	11	12	13	14						20	21
EPTFam	9	10	11	12	13	14			17				21
EphemFam												20	
PlecoFam												20	
TrichFam												20	
ScrapFamPct	9			12	13								
ScrapFam		10	11			14			17			20	21
ClngrFamPct			11	12	13	14							
HBI_Fam	9	10	11	12	13	14			17			20	
adjHBI_Fam													21
Ref 75th %ile	79	84	84	78	79	82	81	82	82	73	76	79	80
Ref 25th %ile	52	64	62	52	52	62	64	62	60	58	59	59	65
Ref Quartile Range	27	20	22	26	27	20	18	20	22	15	17	20	15
Calibration DE	95	100	98	95	95	98	100	100	98	100	100	100	100
Ref Median	68	73	74	68	69	73	72	74	72	65	69	71	73
Stress Median	16	19	19	17	17	20	21	21	23	18	17	15	19
Quartile Z-score	1.9	2.6	2.5	1.9	1.9	2.7	2.9	2.7	2.3	3.1	3	2.8	3.6
Mann-Whitney Z	7.2	7.4	7.4	7.2	7.2	7.3	7.4	7.4	7.3	7.4	7.5	7.5	7.4
Verif. Stress <refcal25	100	100	100	100	100	100	100	100	100	100	100	100	100
Verif. Ref >refcal25	88	63	63	88	88	75	50	63	50	50	63	63	50

Table D-3. Index alternatives and performance statistics.

Metric Code	22	23	24	25	26	27	28	29	30
adjTotalTax						27	28	29	30
NonInsPT	22	23	24	25	26		28	29	
EPTTax						27	28		
adjEphemTax	22	23	24						
PlecoTax	22	23	24						
TrichTax	22	23	24						
adjEPTnHPct	22	23	24	25	26	27		29	30
adjEPTnHBPct							28		
adjScrapTax	22	23	24	25	26	27	28	29	30
adjHBI		23		25		27		29	30
adjTALUTaxaBI			24						
adjTALUBI	22				26		28		
Att23Taxa				25	26			29	30
Ref 75th %ile	74.8	73.0	73.9	73.9	76.1	73.7	76.6	77.2	74.8
Ref 25th %ile	55.1	55.2	55.2	62.0	63.3	57.5	61.5	64.0	59.1
Ref Quartile Range	19.7	17.8	18.7	11.9	12.8	16.2	15.1	13.2	15.8
Calibration DE	100	100	100	100	100	100	100	100	100
Ref Median	66.5	66.0	67.1	68.1	69.2	66.1	71.4	71.7	68.0
Stress Median	15.9	17.2	17.3	19.3	20.0	22.1	26.6	25.5	22.2
Z-score	2.6	2.7	2.7	4.1	3.8	2.7	3.0	3.5	2.9
Mann-Whitney-U Z	7.49	7.43	7.47	7.44	7.47	7.31	7.46	7.43	7.39
Verif. Stress <refcal25	100	100	100	100	100	100	100	100	100
Verif. Ref >refcal25	62.5	62.5	50.0	50.0	50.0	62.5	50.0	62.5	62.5

Table D-4. Index alternatives and performance statistics.

Metric code	31	32	33	34	35	36	37	38	39	40	**41**
TotalTax								38			
adjTotalTax	31	32	33	34			37		39		41
NonInsPT	31	32	33	34	35	36	37	38	39	40	41
EPTTax						36					
adjEPTnHPct		32		34	35	36		38	39	40	
adjEPTnHBPct	31		33				37				
adjSEPTPct											41
adjScrapTax	31	32	33	34	35	36	37	38	39	40	41
adjHBI	31							38	39	40	41
adjTALUBI		32	33	34	35	36	37				
Att2Taxa				34	35		37	38	39	40	41
Att3Taxa				34	35		37	38	39	40	41
Att23Taxa	31	32	33								
Ref 75th %ile	78.1	77.9	78.5	76.5	72.8	76.3	77.2	73.4	74.4	73.0	74.5
Ref 25th %ile	60.2	65.7	63.2	66.3	63.0	61.0	61.8	64.6	64.9	61.4	64.8
Ref Quartile Range	17.9	12.2	15.2	10.2	9.8	15.3	15.4	8.8	9.5	11.6	9.7
Calibration DE	100	100	100	100	100	100	100	100	100	100	100
Ref Median	71.1	71.1	71.3	70.2	67.1	69.3	70.1	69.5	69.1	67.7	69.1
Stress Median	25.6	26.5	24.1	22.7	17.6	19.9	21.5	21.6	21.9	17.1	21.3
Z-score	2.5	3.6	3.1	4.7	5.0	3.2	3.2	5.4	5.0	4.3	4.9
Mann-Whitney-U Z	7.48	7.45	7.49	7.47	7.48	7.47	7.51	7.47	7.47	7.47	7.47
Valid. Stress <refcal25	100	100	100	100	100	100	100	100	100	100	100
Validation Ref >refcal25	62.5	50.0	50.0	50.0	50.0	50.0	62.5	50.0	50.0	50.0	50.0

Appendix E

Metric and Index Values

Only reference and stressed site data are shown.

Table E-1. Genus level metrics and HGMI.

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
Reference sites - HGMI genus											
HW21	Bear Swamp Brook	7/7/03	**Calibration**	16	6.3	57.6	3	4.58	5	6	64.8
AN0245	Beaver Bk	7/21/98	Not used	24	12.5	36.8	5	3.21	5	6	70.1
AN0245	Beaver Bk	7/12/01	**Calibration**	25	16.0	30.1	4	3.88	7	6	68.4
AN0245	Beaver Bk	10/2/01	Not used	31	9.7	47.8	6	3.02	8	9	87.1
AN0245	Beaver Bk	4/4/02	Not used	27	3.7	44.5	5	2.04	8	11	84.8
AN0245	Beaver Bk	8/21/03	Not used	32	3.1	52.8	7	3.63	7	9	87.5
AN0006	Big Flat Bk	7/15/02	Verification	36	11.1	32.1	7	5.22	7	7	77.2
AN0390	Camp Harmony Br of Stony Bk	4/5/94	Not used	31	25.8	28.8	6	5.07	6	6	64.7
AN0390	Camp Harmony Br of Stony Bk	4/14/99	Not used	17	35.3	20.2	4	2.82	2	4	47.8
AN0390	Camp Harmony Br of Stony Bk	9/9/04	**Calibration**	30	23.3	13.0	5	6.11	2	3	44.7
AN0309A	Clove Bk	6/17/98	**Calibration**	23	17.4	54.9	7	4.02	9	1	68.8
AN0309A	Clove Bk	4/22/03	Not used	28	7.1	54.5	9	3.34	10	7	89.1
HW25	Clove Brook	7/8/03	**Calibration**	24	8.3	53.6	5	3.08	10	5	77.6
HW24	Cooley Brook	7/1/03	Verification	24	8.3	22.9	4	5.06	5	5	58.5
HW20	Criss Brook	7/8/03	**Calibration**	25	4.0	35.7	6	3.65	6	7	74.5
AN0252	Crooked Bk	8/3/93	Not used	17	5.9	41.3	6	3.60	4	7	68.5
AN0252	Crooked Bk	8/4/98	**Calibration**	38	13.2	43.7	7	4.07	3	11	72.7
AN0252	Crooked Bk	9/6/01	Not used	27	22.2	31.7	8	5.07	4	5	61.3
AN0252	Crooked Bk	5/21/02	Not used	28	17.9	82.1	4	3.55	8	7	81.9
AN0252	Crooked Bk	9/25/03	Not used	19	10.5	67.7	3	1.99	5	4	70.3
AN0012	Dunnfield Ck	8/30/01	Not used	25	16.0	66.7	5	3.74	11	6	79.1
AN0012	Dunnfield Ck	6/11/02	Not used	30	23.3	66.0	7	3.07	12	5	82.3
HW03	Dunnfield Creek	7/22/03	**Calibration**	30	10.0	39.8	5	3.83	11	6	77.2
AN0208	Dwars Kill	7/10/98	Not used	35	8.6	34.3	5	4.56	7	7	71.2
AN0208	Dwars Kill	7/2/03	**Calibration**	20	15.0	63.6	3	2.39	9	1	67.5
AN0007	Flat Bk	7/15/02	**Calibration**	27	29.6	11.7	3	6.96	1	4	38.3
HW11	Forked Brook	7/14/03	**Calibration**	27	3.7	38.8	3	3.80	10	6	73.6

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
HW27	Franklin Pond Creek	7/22/03	**Calibration**	28	14.3	27.3	7	3.91	9	5	73.5
HW38	Green Brook	7/1/03	**Calibration**	27	11.1	46.2	4	4.89	6	6	68.0
HW19	Harmony Brook	7/23/03	**Calibration**	26	7.7	44.4	4	3.55	5	6	70.7
HW22	Hewitt Brook	7/1/03	**Calibration**	16	6.3	73.7	2	3.94	6	4	66.3
HW17	Hibernia Brook	7/23/03	**Calibration**	28	14.3	35.8	6	3.96	9	5	73.0
HW26	High Mountain Brook	7/21/03	**Calibration**	24	8.3	64.7	5	2.62	10	6	83.3
AN0028	Jacksonburg Ck	7/17/01	Verification	32	12.5	21.2	5	5.47	4	9	64.0
AN0028	Jacksonburg Ck	10/9/01	Not used	33	15.2	22.4	7	5.33	4	7	64.8
AN0028	Jacksonburg Ck	4/9/02	Not used	26	15.4	23.0	5	3.28	3	11	66.5
AN0294	Lake Lookout Bk (trib to Wawayanda Ck)	6/9/98	Not used	23	26.1	8.0	2	5.79	1	2	33.6
AN0294	Lake Lookout Bk	7/19/01	Verification	20	15.0	26.4	3	4.64	1	5	49.2
AN0294	Lake Lookout Bk	10/11/01	Not used	17	23.5	5.9	4	6.36	0	3	31.9
AN0294	Lake Lookout Bk	5/7/02	Not used	26	23.1	38.9	4	5.72	2	4	50.4
AN0004	Little Flat Bk	7/31/01	**Calibration**	33	9.1	67.9	10	3.55	8	11	92.4
AN0004	Little Flat Bk	10/18/01	Not used	25	12.0	24.8	6	5.83	5	9	63.5
AN0004	Little Flat Bk	5/14/02	Not used	33	9.1	73.0	8	2.45	10	10	94.3
AN0005	Little Flat Bk	7/2/02	**Calibration**	35	22.9	26.6	10	5.91	1	4	55.7
AN0051	Lopatcong Ck	9/1/92	Not used	27	3.7	75.4	11	1.72	11	7	96.7
AN0051	Lopatcong Ck	9/18/97	Not used	24	16.7	58.5	5	3.63	5	9	75.0
HW08	Lopatcong Creek	7/30/03	**Calibration**	24	4.2	44.0	6	3.13	9	3	74.0
AN0066	Lubbers Run	8/4/92	Not used	17	5.9	32.7	5	3.70	2	5	59.7
AN0066	Lubbers Run	8/7/97	Not used	24	29.2	10.4	7	5.47	1	5	47.6
AN0066	Lubbers Run	8/14/01	**Calibration**	26	26.9	12.0	8	5.50	1	9	56.0
AN0066	Lubbers Run	5/29/02	Not used	20	25.0	7.1	6	5.75	2	3	42.1
AN0260	Mossmans Bk	8/5/93	Not used	28	7.1	21.0	5	5.02	2	6	58.7
AN0260	Mossmans Bk	8/6/98	Not used	35	17.1	45.9	7	4.72	4	7	71.7
AN0260	Mossmans Bk	7/19/01	Not used	36	13.9	41.5	10	4.33	3	8	76.8
AN0260	Mossmans Bk	10/11/01	Not used	23	8.7	59.6	6	5.36	2	7	66.0

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0260	Mossmans Bk	5/1/02	Not used	35	14.3	31.8	7	4.64	6	9	75.1
AN0260	Mossmans Bk	9/25/03	Not used	36	22.2	27.4	5	4.77	7	6	67.4
HW07	Mossmans Brook	7/21/03	**Calibration**	27	11.1	21.0	5	4.80	4	8	65.0
AN0064	Musconetcong R	8/4/92	Not used	20	15.0	24.2	2	4.38	1	3	45.8
AN0064	Musconetcong R	8/7/97	**Calibration**	24	20.8	26.5	7	4.31	5	3	60.4
HW10	Parker Brook	7/14/03	**Calibration**	25	0.0	30.2	4	4.07	5	7	68.3
AN0259	Pequannock River	7/22/93	Not used	25	16.0	12.0	4	6.02	1	5	46.2
AN0259	Pequannock River	8/6/98	**Calibration**	38	18.4	20.6	11	5.68	5	7	72.5
AN0259	Pequannock River	10/9/03	Not used	32	18.8	68.5	10	3.38	3	10	83.2
AN0215	Primrose Bk	7/22/03	**Calibration**	29	6.9	48.6	6	3.26	12	4	77.0
AN0399	Rock Bk	4/5/94	Not used	13	15.4	24.2	3	2.10	4	5	56.8
AN0399	Rock Bk	4/27/99	Not used	15	13.3	25.7	6	2.53	3	5	60.7
AN0399	Rock Bk	9/13/01	Not used	22	22.7	34.3	7	4.16	1	8	61.6
AN0399	Rock Bk	6/6/02	**Calibration**	17	5.9	9.6	3	5.35	2	4	44.3
AN0399	Rock Bk	9/21/04	Not used	21	14.3	13.6	4	4.18	1	3	46.1
AN0239	Russia Bk	7/22/93	Not used	28	0.0	11.3	6	4.28	4	7	66.9
AN0239	Russia Bk	7/16/98	**Calibration**	30	6.7	31.5	5	4.19	3	7	68.8
AN0239	Russia Bk	9/16/03	Not used	25	8.0	13.5	6	5.05	2	9	61.1
AN0003	Shimers Bk	7/31/01	**Calibration**	21	14.3	67.6	5	3.60	4	5	69.1
AN0003	Shimers Bk	10/18/01	Not used	16	18.8	73.3	6	2.62	4	6	70.8
AN0003	Shimers Bk	5/22/02	Not used	31	19.4	46.0	6	3.66	4	6	71.6
HW14	Shimmers Brook	7/8/03	**Calibration**	29	6.9	44.3	5	3.37	9	7	81.5
HW06	Sparta Glen Road	7/22/03	Verification	29	13.8	35.3	5	3.99	10	5	72.2
HW13	Stony Brook	7/14/03	**Calibration**	19	10.5	15.8	0	4.87	4	4	46.2
HW15	Stony Brook	7/22/03	**Calibration**	33	9.1	25.8	11	3.45	9	7	85.3
HW12	Tuttles Corner Brook	7/8/03	Verification	28	3.6	44.2	3	3.04	10	5	76.5
AN0225	UNT to Dead River	7/10/01	Not used	12	41.7	1.7	2	6.24	1	2	22.3
AN0225	UNT to Dead River	10/4/01	Not used	19	31.6	4.4	5	5.93	0	4	34.8
AN0225	UNT to Dead River	4/4/02	Not used	23	26.1	3.9	5	5.76	1	4	40.4

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0225	UNT to Dead River	7/31/03	Verification	18	33.3	1.9	4	5.91	1	1	29.1
AN0023A	UNT to Troy Bk	10/9/97	Not used	25	28.0	33.8	8	4.40	4	6	64.5
AN0023A	UNT to Troy Bk	8/6/02	**Calibration**	39	20.5	20.6	9	5.16	5	8	71.8
HW18	UNT to Westbrook	7/20/03	Verification	26	7.7	43.9	6	3.29	5	8	77.2
AN0009	Van Campens Bk	6/12/03	**Calibration**	13	23.1	72.4	0	3.43	6	1	54.1
AN0010	Van Campens Bk	7/16/02	Not used	36	0.0	60.0	9	3.29	14	8	94.1
AN0011	Van Campens Bk	7/17/01	**Calibration**	32	0.0	64.8	13	2.56	12	10	99.7
AN0011	Van Campens Bk	10/9/01	Not used	23	0.0	82.0	10	1.93	6	9	89.8
AN0011	Van Campens Bk	4/11/02	Not used	22	4.5	90.5	8	1.85	8	7	88.6
Stressed sites - HGMI genus											
HW29	Allendale Brook	7/7/03	**Calibration**	21	38.1	1.1	2	6.38	1	3	28.3
AN0116	Assunpink Ck	6/3/03	Verification	18	50.0	0.0	4	6.38	0	0	21.8
AN0222	Black Bk	7/24/03	Verification	18	66.7	0.0	2	7.74	0	1	16.1
AN0424B	Bound Bk	6/17/04	**Calibration**	14	78.6	0.0	2	6.30	0	0	12.3
HW30	Canoe Brook	7/9/03	Verification	13	15.4	1.0	1	6.14	1	3	29.4
AN0271	Deepavaal Bk	7/7/93	Not used	17	35.3	0.0	4	7.48	0	0	19.1
AN0271	Deepavaal Bk	8/5/98	**Calibration**	18	44.4	0.0	2	7.40	0	0	14.8
AN0271	Deepavaal Bk	9/6/01	Not used	15	53.3	0.9	2	7.38	0	1	13.2
AN0271	Deepavaal Bk	5/21/02	Not used	18	61.1	0.0	4	7.76	0	0	13.1
AN0271	Deepavaal Bk	10/23/03	Not used	18	61.1	0.0	3	7.37	0	0	12.2
HW32	Demarest Brook	7/16/03	**Calibration**	20	20.0	5.0	2	6.12	0	2	29.7
AN0278	Diamond Bk	7/7/93	Not used	19	47.4	3.4	1	7.16	0	0	14.1
AN0278	Diamond Bk	8/11/98	Verification	16	50.0	0.0	1	6.64	0	0	13.1
HW33	East Br of Rahway River	7/29/03	**Calibration**	17	23.5	0.0	1	6.74	1	2	25.6
AN0204	Elizabeth River	9/16/98	**Calibration**	19	31.6	28.0	1	5.47	0	0	30.0
AN0204	Elizabeth River	10/21/04	Not used	18	38.9	0.9	1	7.12	1	2	22.3
AN0277	Goffle Bk	7/7/93	Not used	14	28.6	0.0	2	5.97	0	0	21.7
AN0277	Goffle Bk	8/11/98	**Calibration**	19	42.1	0.0	3	6.97	0	0	18.7
AN0277	Goffle Bk	10/30/03	Not used	11	18.2	0.0	1	5.22	0	0	24.1

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0277A	Goffle Bk	9/15/98	Not used	9	88.9	0.0	1	6.37	0	0	8.2
AN0277A	Goffle Bk	7/1/04	Not used	26	26.9	10.6	3	5.90	1	2	36.3
HW37	Goffle Brook	7/7/03	**Calibration**	17	23.5	5.9	1	6.13	1	2	28.7
AN0107	Gold Run	7/13/92	Not used	21	28.6	16.7	3	5.15	0	0	31.3
AN0107	Gold Run	7/1/97	**Calibration**	21	23.8	15.2	3	5.41	0	1	33.2
AN0107	Gold Run	5/13/03	Not used	15	40.0	1.9	3	6.83	0	1	19.2
HW41	Hirshfeld Brook	7/16/03	**Calibration**	17	11.8	10.0	1	6.01	1	2	32.9
AN0288	Hohokus Bk	7/17/90	Not used	17	23.5	0.0	1	5.83	0	1	26.3
AN0288	Hohokus Bk	8/18/98	Verification	22	40.9	0.7	4	6.94	0	0	22.5
AN0288	Hohokus Bk	10/28/03	Not used	19	57.9	0.0	4	7.12	0	1	17.8
AN0220	Loantaka Bk	7/24/03	**Calibration**	14	50.0	0.0	2	6.51	1	1	17.8
AN0086	Lockatong Ck	7/15/97	**Calibration**	23	17.4	17.9	6	4.96	1	6	52.1
AN0086	Lockatong Ck	5/1/03	Not used	25	12.0	39.2	5	4.55	4	3	58.8
AN0429	Mile Run	10/13/98	Not used	18	61.1	0.0	4	8.47	0	0	13.1
AN0429	Mile Run	6/12/02	Not used	13	46.2	0.0	0	8.21	0	0	9.8
AN0429	Mile Run	6/17/04	**Calibration**	14	57.1	0.0	1	7.25	1	0	10.5
AN0436	Mill Bk	7/13/99	Not used	7	42.9	21.2	1	5.14	0	1	21.7
AN0436	Mill Bk	7/8/04	Not used	19	36.8	15.4	1	5.94	1	2	28.7
HW42	Mill Brook	7/31/03	Verification	14	14.3	8.2	1	5.74	1	1	29.5
HW43	Morses Creek	7/2/03	**Calibration**	19	31.6	7.1	2	7.28	1	2	25.7
AN0206	Musquapsink Bk	7/6/93	Not used	11	54.5	0.0	4	6.19	0	0	15.4
AN0206	Musquapsink Bk	7/9/98	Not used	19	31.6	4.8	5	6.27	0	0	27.1
AN0206	Musquapsink Bk	8/21/01	Not used	13	30.8	4.0	2	6.97	0	1	20.1
AN0206	Musquapsink Bk	6/5/02	Not used	20	50.0	5.6	4	6.94	0	0	19.5
AN0206	Musquapsink Bk	7/1/03	**Calibration**	16	50.0	0.0	2	6.71	0	0	14.7
HW45	Naachtpunkt Brook	7/9/03	**Calibration**	16	25.0	0.0	1	5.35	0	1	25.8
HW46	Nomehegan Brook	7/2/03	**Calibration**	13	23.1	1.0	2	6.07	0	0	21.9
HW47	Overpeck	7/16/03	**Calibration**	14	7.1	4.9	2	6.68	0	2	29.4
AN0212	Overpeck Ck	7/6/93	Not used	14	21.4	2.9	2	7.00	0	2	23.6

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0212	Overpeck Ck	7/10/98	Not used	19	52.6	6.8	3	6.60	0	0	17.6
AN0212	Overpeck Ck	7/2/03	**Calibration**	19	21.1	0.9	0	6.29	0	1	23.7
AN0270	Packanack Bk	7/12/93	Not used	14	35.7	0.0	3	6.53	0	0	19.4
AN0270	Packanack Bk	8/5/98	**Calibration**	16	37.5	1.0	1	5.72	0	0	19.8
AN0270	Packanack Bk	10/15/03	Not used	11	54.5	0.0	1	5.75	0	0	13.0
AN0307	Papakating Ck	6/27/90	Not used	23	21.7	45.7	8	4.98	1	4	57.9
AN0307	Papakating Ck	6/10/98	**Calibration**	21	33.3	5.1	7	6.86	2	1	34.9
AN0307	Papakating Ck	7/24/01	Not used	29	24.1	5.5	7	6.22	3	3	48.3
AN0307	Papakating Ck	10/30/01	Not used	17	35.3	1.6	4	6.87	1	1	26.1
AN0307	Papakating Ck	5/29/02	Not used	20	50.0	0.0	2	7.73	0	0	14.4
AN0307	Papakating Ck	4/22/03	Not used	28	21.4	1.3	6	6.93	1	3	40.6
AN0207	Pascack Bk	7/6/93	Not used	19	21.1	1.6	2	5.31	1	0	30.9
AN0207	Pascack Bk	7/9/98	Not used	17	35.3	2.9	1	5.22	0	0	24.7
AN0207	Pascack Bk	7/1/03	Verification	22	27.3	4.0	3	6.20	1	2	33.3
AN0192	Rahway River	10/13/04	**Calibration**	16	43.8	0.0	3	8.93	0	0	15.3
AN0194	Rahway River	10/13/04	**Calibration**	14	57.1	0.0	1	7.15	0	0	11.2
AN0195	Rahway River	10/21/04	Not used	15	46.7	1.8	6	5.54	0	0	25.5
HW51	Rahway River	7/19/03	Verification	16	18.8	9.9	1	6.46	1	1	27.5
AN0267	Ramapo River	7/10/90	Not used	22	36.4	12.1	4	5.91	0	2	32.2
AN0267	Ramapo River	8/7/98	**Calibration**	21	23.8	29.4	4	4.58	0	3	41.2
AN0267	Ramapo River	10/21/03	Not used	20	30.0	27.5	4	4.85	0	4	39.7
AN0199	Robinsons Br	10/21/04	Verification	10	50.0	0.0	2	6.06	0	0	14.6
AN0412	Royce Bk Br	9/30/04	Verification	16	50.0	1.0	2	6.33	0	1	17.3
AN0279	Saddle R	7/17/90	Not used	18	16.7	17.9	5	4.21	1	2	44.9
AN0279	Saddle R	8/14/98	Not used	24	16.7	4.8	7	4.76	2	1	45.8
AN0279	Saddle R	7/8/03	**Calibration**	29	31.0	28.0	6	5.98	2	2	45.9
AN0281	Saddle R	7/17/90	Not used	25	24.0	6.1	5	5.39	0	1	37.1
AN0281	Saddle R	8/13/98	Not used	32	21.9	8.1	5	5.63	0	2	42.4
AN0281	Saddle R	7/10/03	Not used	30	16.7	13.6	5	6.00	1	2	44.6

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0282	Saddle R	7/17/90	Not used	19	21.1	4.5	5	4.87	0	1	36.7
AN0282	Saddle R	8/14/98	**Calibration**	23	26.1	1.8	5	5.14	0	2	37.6
AN0282	Saddle R	10/28/03	Not used	16	25.0	5.6	3	4.86	1	0	31.9
AN0289	Saddle R	7/17/90	Not used	13	30.8	0.0	1	5.64	0	0	22.8
AN0289	Saddle R	8/18/98	Not used	22	36.4	0.0	4	6.21	0	0	26.4
AN0289	Saddle R	10/28/03	Not used	16	31.3	0.0	1	5.56	0	0	24.3
AN0290	Saddle R	7/17/90	Not used	13	30.8	0.0	0	6.88	0	0	19.3
AN0290	Saddle R	8/18/98	Not used	23	26.1	0.9	2	7.41	0	0	23.7
AN0291	Saddle R	7/17/90	Not used	13	38.5	0.0	0	7.46	1	0	17.5
AN0291	Saddle R	8/18/98	Not used	22	50.0	25.2	2	6.57	0	0	24.8
AN0435	Sawmill Bk	9/30/93	Not used	20	55.0	0.0	3	7.62	0	1	16.1
AN0435	Sawmill Bk	9/10/98	Not used	28	42.9	0.9	2	8.20	0	1	21.8
AN0435	Sawmill Bk	7/29/04	**Calibration**	21	61.9	0.0	5	8.77	0	0	16.1
AN0293	Second River	6/24/04	**Calibration**	12	33.3	7.8	2	8.24	0	1	17.7
HW52	Second River	7/19/03	**Calibration**	11	27.3	0.0	1	7.09	1	0	17.3
AN0200	South Br Rahway River	10/7/04	**Calibration**	15	53.3	0.0	2	5.28	0	0	17.9
AN0201	South Br Rahway River	8/9/01	Not used	21	23.8	2.4	2	6.85	1	1	27.5
AN0201	South Br Rahway River	6/12/02	**Calibration**	17	47.1	7.4	0	8.11	1	1	16.7
AN0201	South Br Rahway River	10/5/04	Not used	18	38.9	1.0	2	5.22	0	1	25.2
AN0209	Tenakill Bk	7/6/93	Not used	14	35.7	0.0	1	7.83	0	0	13.5
AN0209	Tenakill Bk	7/9/98	Not used	16	56.3	0.0	2	8.96	0	0	10.3
AN0209	Tenakill Bk	7/1/03	**Calibration**	22	59.1	0.0	3	7.53	0	0	14.0
AN0292	Third River	7/6/93	Not used	16	43.8	5.0	5	5.39	1	0	27.5
AN0292	Third River	8/19/98	**Calibration**	14	57.1	5.4	1	4.61	0	0	18.7
AN0292A	Third River	9/25/98	**Calibration**	16	62.5	0.0	3	6.32	0	0	14.3
HW53	Third River	7/17/03	**Calibration**	18	27.8	2.1	2	5.59	1	2	30.4
HW54	UNT to Passaic River	7/28/03	**Calibration**	18	11.1	2.0	1	5.72	0	2	30.9
AN0197	UNT to Robinsons Br	10/7/04	**Calibration**	16	43.8	0.0	2	5.18	0	0	20.7
AN0198	UNT to Robinsons Br	10/7/04	**Calibration**	14	64.3	0.0	2	7.23	0	0	10.1

Station	Waterbody Name	CollDate	CalVer	TotalTax	NonInsPT	sEPTpct	ScrapTax	HBI	Att2Taxa	Att3Taxa	HGMIgen
AN0110	UNT to Shipetaukin Ck	6/3/03	**Calibration**	19	57.9	0.8	3	7.99	0	1	19.6
AN0284	Valentine Bk	7/16/90	Not used	19	36.8	0.0	3	6.02	0	1	24.2
AN0284	Valentine Bk	8/13/98	Not used	17	29.4	0.0	4	5.54	0	0	26.2
AN0284	Valentine Bk	8/21/01	Not used	14	35.7	0.0	2	5.13	0	0	21.9
AN0284	Valentine Bk	6/5/02	Not used	13	30.8	0.0	2	7.84	0	0	16.5
AN0284	Valentine Bk	7/30/03	**Calibration**	26	26.9	0.0	5	6.32	1	1	33.5
AN0211	Van Saun Bk	7/6/93	Not used	15	33.3	0.0	2	6.67	0	0	18.5
AN0211	Van Saun Bk	7/10/98	Not used	15	53.3	0.0	4	6.36	0	0	16.9
AN0211	Van Saun Bk	7/8/03	**Calibration**	25	48.0	0.0	2	7.40	0	1	18.8
AN0280	W Br Saddle River	7/17/90	Not used	24	8.3	9.3	7	4.03	2	4	55.7
AN0280	W Br Saddle River	8/14/98	Not used	18	16.7	12.4	5	5.35	2	1	39.4
AN0280	W Br Saddle River	7/8/03	**Calibration**	26	30.8	32.0	5	6.22	2	2	42.5
AN0202	West Br Elizabeth River	9/16/98	Not used	19	47.4	0.0	0	6.74	0	0	13.5
HW55	West Br Elizabeth River	7/2/03	**Calibration**	15	20.0	0.0	2	6.57	1	0	23.7
HW56	West Br of Shabakunk Crk	7/29/03	Verification	19	15.8	2.0	3	5.56	1	1	33.1

Table E-2. Family level metrics and HGMI, as well as the family level NJIS and the genus level BCG Tiers.

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
Reference sites - HGMI genus											
HW21	Bear Swamp Brook	7/7/03	**Calibration**	10	7.7	57.6	4.31	4	80.1	2	27
AN0245	Beaver Bk	7/21/98	Not used	8	17.6	36.0	3.46	5	77.3	2	30
AN0245	Beaver Bk	7/12/01	**Calibration**	8	17.6	30.1	3.86	5	73.5	2	30
AN0245	Beaver Bk	10/2/01	Not used	11	13.0	40.7	3.18	6	89.8	2	30
AN0245	Beaver Bk	4/4/02	Not used	11	5.6	42.7	3.86	4	82.4	2	27
AN0245	Beaver Bk	8/21/03	Not used	11	5.3	48.1	3.39	5	89.7	2	30
AN0006	Big Flat Bk	7/15/02	Verification	12	14.3	29.0	4.96	5	79.6	3	24
AN0390	Camp Harmony Br of Stony Bk	4/5/94	Not used	8	29.2	28.8	5.78	3	50.4	3	24
AN0390	Camp Harmony Br of Stony Bk	4/14/99	Not used	5	40.0	20.2	5.34	1	34.9	3.5	15
AN0390	Camp Harmony Br of Stony Bk	9/9/04	**Calibration**	5	33.3	13.0	5.69	4	43.2	5	21
AN0309A	Clove Bk	6/17/98	**Calibration**	10	23.5	54.9	4.15	5	81.5	2	30
AN0309A	Clove Bk	4/22/03	Not used	12	10.0	54.5	4.20	6	92.2	2	30
HW25	Clove Brook	7/8/03	**Calibration**	12	11.1	44.3	3.51	6	87.3	2	30
HW24	Cooley Brook	7/1/03	Verification	7	14.3	22.9	4.65	3	56.1	3	27
HW20	Criss Brook	7/8/03	**Calibration**	10	6.3	32.7	4.38	5	73.1	2	27
AN0252	Crooked Bk	8/3/93	Not used	9	7.1	41.3	3.20	4	77.2	2	30
AN0252	Crooked Bk	8/4/98	**Calibration**	10	22.7	39.8	3.53	6	78.5	3	30
AN0252	Crooked Bk	9/6/01	Not used	8	27.8	29.7	4.56	3	55.4	3	30
AN0252	Crooked Bk	5/21/02	Not used	13	22.7	81.3	3.00	4	87.2	2	30
AN0252	Crooked Bk	9/25/03	Not used	9	12.5	45.5	3.25	4	76.5	3	30
AN0012	Dunnfield Ck	8/30/01	Not used	13	21.1	54.7	3.75	5	85.3	2	30
AN0012	Dunnfield Ck	6/11/02	Not used	11	28.6	63.0	3.32	5	85.9	2	30
HW03	Dunnfield Creek	7/22/03	**Calibration**	13	15.0	38.8	4.28	3	73.2	2	27
AN0208	Dwars Kill	7/10/98	Not used	10	15.0	33.3	4.62	4	63.1	3	30
AN0208	Dwars Kill	7/2/03	**Calibration**	9	20.0	62.1	3.78	3	69.3	2	30
AN0007	Flat Bk	7/15/02	**Calibration**	7	33.3	11.7	6.73	3	46.4	4	24

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
HW11	Forked Brook	7/14/03	**Calibration**	13	5.9	31.6	4.23	4	74.2	2	27
HW27	Franklin Pond Creek	7/22/03	**Calibration**	8	25.0	22.2	4.33	5	66.6	2	30
HW38	Green Brook	7/1/03	**Calibration**	7	17.6	44.2	3.75	3	65.9	2	30
HW19	Harmony Brook	7/23/03	**Calibration**	8	11.8	44.4	4.10	3	68.7	3	30
HW22	Hewitt Brook	7/1/03	**Calibration**	9	8.3	71.6	3.87	3	77.9	2	30
HW17	Hibernia Brook	7/23/03	**Calibration**	10	21.1	22.1	4.66	4	62.5	2	30
HW26	High Mountain Brook	7/21/03	**Calibration**	14	10.0	51.0	3.61	5	86.6	2	30
AN0028	Jacksonburg Ck	7/17/01	Verification	10	19.0	20.3	5.03	5	64.8	3	21
AN0028	Jacksonburg Ck	10/9/01	Not used	9	19.0	20.6	5.64	5	60.2	3	24
AN0028	Jacksonburg Ck	4/9/02	Not used	8	23.5	23.0	4.94	3	54.6	3	24
AN0294	Lake Lookout Bk (trib to Wawayanda Ck)	6/9/98	Not used	4	42.9	8.0	4.50	2	37.8	5	21
AN0294	Lake Lookout Bk	7/19/01	Verification	7	20.0	26.4	4.08	3	61.0	4	27
AN0294	Lake Lookout Bk	10/11/01	Not used	5	30.8	5.9	5.40	4	44.8	5	15
AN0294	Lake Lookout Bk	5/7/02	Not used	6	35.3	38.9	5.11	4	56.3	4	27
AN0004	Little Flat Bk	7/31/01	**Calibration**	14	13.6	56.9	3.41	6	89.0	2	30
AN0004	Little Flat Bk	10/18/01	Not used	12	11.1	23.9	4.99	5	68.7	2.5	21
AN0004	Little Flat Bk	5/14/02	Not used	14	12.5	73.0	2.29	5	94.7	2	30
AN0005	Little Flat Bk	7/2/02	**Calibration**	7	42.1	26.6	6.10	5	50.2	4	24
AN0051	Lopatcong Ck	9/1/92	Not used	12	5.6	73.2	2.99	6	99.5	2	30
AN0051	Lopatcong Ck	9/18/97	Not used	10	22.2	56.1	3.93	4	76.1	2	30
HW08	Lopatcong Creek	7/30/03	**Calibration**	11	6.7	44.0	3.90	4	78.1	2	30
AN0066	Lubbers Run	8/4/92	Not used	8	9.1	32.7	3.64	3	74.1	3	27
AN0066	Lubbers Run	8/7/97	Not used	6	36.8	10.4	4.69	4	53.4	5	27
AN0066	Lubbers Run	8/14/01	**Calibration**	7	35.3	12.0	4.85	5	58.5	4	27
AN0066	Lubbers Run	5/29/02	Not used	6	35.7	7.1	4.66	4	52.9	5	24
AN0260	Mossmans Bk	8/5/93	Not used	8	12.5	21.0	4.86	5	65.9	4	24
AN0260	Mossmans Bk	8/6/98	Not used	10	30.0	45.9	4.16	7	78.0	3	30

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0260	Mossmans Bk	7/19/01	Not used	11	20.8	41.5	3.82	7	82.9	3	30
AN0260	Mossmans Bk	10/11/01	Not used	8	14.3	59.6	4.22	3	73.4	3.5	30
AN0260	Mossmans Bk	5/1/02	Not used	10	21.7	31.8	4.43	7	75.0	3	27
AN0260	Mossmans Bk	9/25/03	Not used	11	25.0	27.4	4.84	5	68.9	3	30
HW07	Mossmans Brook	7/21/03	**Calibration**	6	18.8	20.0	4.65	4	57.8	3	24
AN0064	Musconetcong R	8/4/92	Not used	5	25.0	24.2	4.37	3	58.9	4	27
AN0064	Musconetcong R	8/7/97	**Calibration**	8	31.3	26.5	3.67	4	69.4	3	30
HW10	Parker Brook	7/14/03	**Calibration**	9	0.0	22.9	4.13	3	65.7	3	30
AN0259	Pequannock River	7/22/93	Not used	8	25.0	12.0	5.21	3	55.3	4	18
AN0259	Pequannock River	8/6/98	**Calibration**	10	30.0	20.6	5.32	6	69.1	4	18
AN0259	Pequannock River	10/9/03	Not used	12	25.0	68.5	3.33	6	94.3	3	30
AN0215	Primrose Bk	7/22/03	**Calibration**	12	9.1	45.0	3.61	4	78.2	2	30
AN0399	Rock Bk	4/5/94	Not used	6	16.7	24.2	5.37	2	49.1	2	18
AN0399	Rock Bk	4/27/99	Not used	4	16.7	25.7	4.83	5	59.0	2	18
AN0399	Rock Bk	9/13/01	Not used	7	29.4	34.3	3.73	6	71.3	4	30
AN0399	Rock Bk	6/6/02	**Calibration**	6	11.1	9.6	1.83	4	65.0	4.5	21
AN0399	Rock Bk	9/21/04	Not used	5	23.1	13.6	4.18	4	54.9	5	27
AN0239	Russia Bk	7/22/93	Not used	8	0.0	11.3	4.01	5	72.0	3	24
AN0239	Russia Bk	7/16/98	**Calibration**	11	10.5	31.5	3.81	4	79.6	3	30
AN0239	Russia Bk	9/16/03	Not used	8	10.5	13.5	4.01	5	71.6	3.5	24
AN0003	Shimers Bk	7/31/01	**Calibration**	9	12.5	67.6	3.95	5	86.2	3	27
AN0003	Shimers Bk	10/18/01	Not used	8	20.0	64.8	3.40	5	84.9	2	30
AN0003	Shimers Bk	5/22/02	Not used	10	18.2	38.7	4.10	4	74.8	3	30
HW14	Shimmers Brook	7/8/03	**Calibration**	14	9.5	43.3	3.64	5	85.4	2	30
HW06	Sparta Glen Road	7/22/03	Verification	10	21.1	35.3	4.07	4	69.8	2	30
HW13	Stony Brook	7/14/03	**Calibration**	6	18.2	15.8	5.08	1	43.2	3	18
HW15	Stony Brook	7/22/03	**Calibration**	14	13.0	24.7	3.67	6	81.8	2	27
HW12	Tuttles Corner Brook	7/8/03	Verification	11	5.6	38.9	3.69	4	80.4	2	30

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0225	UNT to Dead River	7/10/01	Not used	2	44.4	1.7	4.44	2	28.3	5	9
AN0225	UNT to Dead River	10/4/01	Not used	4	31.3	4.4	4.91	5	43.5	5	18
AN0225	UNT to Dead River	4/4/02	Not used	5	31.3	3.9	5.70	4	37.8	5	21
AN0225	UNT to Dead River	7/31/03	Verification	3	46.2	1.9	5.00	2	26.6	5	15
AN0023A	UNT to Troy Bk	10/9/97	Not used	9	35.0	28.6	4.44	6	70.7	3	30
AN0023A	UNT to Troy Bk	8/6/02	**Calibration**	10	29.6	19.6	4.96	6	68.8	3	27
HW18	UNT to Westbrook	7/20/03	Verification	7	14.3	40.8	3.65	4	69.2	2	30
AN0009	Van Campens Bk	6/12/03	**Calibration**	6	27.3	72.4	2.85	0	63.0	3	27
AN0010	Van Campens Bk	7/16/02	Not used	15	0.0	60.0	3.57	5	93.0	2	30
AN0011	Van Campens Bk	7/17/01	**Calibration**	15	0.0	64.8	2.78	8	100.0	2	30
AN0011	Van Campens Bk	10/9/01	Not used	11	0.0	82.0	2.71	4	91.7	2	30
AN0011	Van Campens Bk	4/11/02	Not used	11	6.3	90.5	2.91	5	95.0	2	30
Stressed sites - HGMI genus											
HW29	Allendale Brook	7/7/03	**Calibration**	2	58.3	1.1	5.99	1	13.9	4	15
AN0116	Assunpink Ck	6/3/03	Verification	1	69.2	0.0	4.99	2	14.4	5	15
AN0222	Black Bk	7/24/03	Verification	0	72.7	0.0	7.66	1	3.3	5	12
AN0424B	Bound Bk	6/17/04	**Calibration**	0	90.9	0.0	7.19	1	4.3	5	12
HW30	Canoe Brook	7/9/03	Verification	2	33.3	1.0	6.01	1	23.1	4	6
AN0271	Deepavaal Bk	7/7/93	Not used	1	55.6	0.0	6.71	2	16.5	5	9
AN0271	Deepavaal Bk	8/5/98	**Calibration**	0	77.8	0.0	6.64	2	10.6	5	9
AN0271	Deepavaal Bk	9/6/01	Not used	1	70.0	0.9	6.76	3	15.3	5	12
AN0271	Deepavaal Bk	5/21/02	Not used	0	81.8	0.0	6.70	3	13.6	5	15
AN0271	Deepavaal Bk	10/23/03	Not used	0	81.8	0.0	7.14	1	4.8	5	12
HW32	Demarest Brook	7/16/03	**Calibration**	3	30.8	5.0	6.08	2	27.3	5	21
AN0278	Diamond Bk	7/7/93	Not used	2	64.3	3.4	6.83	1	10.0	5	12
AN0278	Diamond Bk	8/11/98	Verification	1	72.7	0.0	6.40	1	7.8	5	12
HW33	East Branch of Rahway River	7/29/03	**Calibration**	1	50.0	0.0	6.39	0	11.8	5	12
AN0204	Elizabeth River	9/16/98	**Calibration**	3	46.2	28.0	4.99	1	39.0	5	27

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0204	Elizabeth River	10/21/04	Not used	2	50.0	0.9	6.72	2	22.7	5	21
AN0277	Goffle Bk	7/7/93	Not used	1	44.4	0.0	5.33	1	24.4	5	15
AN0277	Goffle Bk	8/11/98	**Calibration**	1	61.5	0.0	6.82	2	14.9	5	12
AN0277	Goffle Bk	10/30/03	Not used	1	28.6	0.0	4.46	1	33.8	5	18
AN0277A	Goffle Bk	9/15/98	Not used	0	88.9	0.0	6.33	1	7.5	6	9
AN0277A	Goffle Bk	7/1/04	Not used	3	40.0	10.6	5.46	2	32.9	4	21
HW37	Goffle Brook	7/7/03	**Calibration**	3	44.4	5.9	5.91	1	24.5	4.5	9
AN0107	Gold Run	7/13/92	Not used	3	40.0	16.7	4.47	4	44.3	5	27
AN0107	Gold Run	7/1/97	**Calibration**	4	30.8	15.2	4.83	3	43.3	5	24
AN0107	Gold Run	5/13/03	Not used	2	45.5	1.9	5.83	3	26.4	5	15
HW41	Hirshfeld Brook	7/16/03	**Calibration**	3	25.0	10.0	5.41	1	34.0	4	18
AN0288	Hohokus Bk	7/17/90	Not used	1	44.4	0.0	5.30	1	26.7	5	15
AN0288	Hohokus Bk	8/18/98	Verification	2	53.3	0.7	6.62	3	25.8	5	18
AN0288	Hohokus Bk	10/28/03	Not used	1	62.5	0.0	7.74	3	16.7	5	12
AN0220	Loantaka Bk	7/24/03	**Calibration**	1	60.0	0.0	5.25	1	15.8	5	12
AN0086	Lockatong Ck	7/15/97	**Calibration**	7	25.0	17.9	4.43	5	58.7	4	30
AN0086	Lockatong Ck	5/1/03	Not used	8	17.6	39.2	4.08	5	70.8	4	30
AN0429	Mile Run	10/13/98	Not used	1	73.3	0.0	7.00	3	13.4	5	9
AN0429	Mile Run	6/12/02	Not used	1	71.4	0.0	8.00	0	2.6	5	6
AN0429	Mile Run	6/17/04	**Calibration**	1	70.0	0.0	6.53	0	5.8	5	9
AN0436	Mill Bk	7/13/99	Not used	2	50.0	21.2	4.23	1	33.9	6	15
AN0436	Mill Bk	7/8/04	Not used	3	58.3	15.4	5.32	1	25.8	5	24
HW42	Mill Brook	7/31/03	Verification	2	33.3	8.2	5.03	1	30.9	5	15
HW43	Morses Creek	7/2/03	**Calibration**	3	45.5	7.1	6.91	1	17.9	5	15
AN0206	Musquapsink Bk	7/6/93	Not used	1	55.6	0.0	4.70	2	26.7	5	9
AN0206	Musquapsink Bk	7/9/98	Not used	2	60.0	4.8	5.19	3	29.4	5	15
AN0206	Musquapsink Bk	8/21/01	Not used	2	50.0	4.0	5.85	3	28.9	5	9
AN0206	Musquapsink Bk	6/5/02	Not used	2	66.7	5.6	5.92	2	20.5	5	15

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0206	Musquapsink Bk	7/1/03	**Calibration**	1	63.6	0.0	5.99	1	14.4	5	15
HW45	Naachtpunkt Brook	7/9/03	**Calibration**	1	50.0	0.0	5.40	1	18.3	4	6
HW46	Nomehegan Brook	7/2/03	**Calibration**	2	33.3	1.0	4.82	1	29.3	5	12
HW47	Overpeck	7/16/03	**Calibration**	1	33.3	4.9	5.91	1	25.2	5	3
AN0212	Overpeck Ck	7/6/93	Not used	2	33.3	2.9	5.80	1	24.0	5	6
AN0212	Overpeck Ck	7/10/98	Not used	2	66.7	6.8	6.18	2	16.0	5	15
AN0212	Overpeck Ck	7/2/03	**Calibration**	2	42.9	0.9	6.49	0	14.0	5	9
AN0270	Packanack Bk	7/12/93	Not used	1	50.0	0.0	4.74	2	24.4	5	15
AN0270	Packanack Bk	8/5/98	**Calibration**	2	45.5	1.0	4.96	1	23.1	5	21
AN0270	Packanack Bk	10/15/03	Not used	1	55.6	0.0	4.86	1	18.7	5	18
AN0307	Papakating Ck	6/27/90	Not used	6	33.3	45.7	4.77	4	66.8	4	30
AN0307	Papakating Ck	6/10/98	**Calibration**	4	50.0	5.1	5.81	4	40.9	5	18
AN0307	Papakating Ck	7/24/01	Not used	6	43.8	5.5	5.38	5	51.8	5	18
AN0307	Papakating Ck	10/30/01	Not used	3	46.2	1.6	5.64	2	33.6	5	18
AN0307	Papakating Ck	5/29/02	Not used	0	70.0	0.0	6.80	1	11.4	5	12
AN0307	Papakating Ck	4/22/03	Not used	3	38.5	1.3	6.45	4	38.6	5	12
AN0207	Pascack Bk	7/6/93	Not used	2	37.5	1.6	4.83	1	34.6	5	18
AN0207	Pascack Bk	7/9/98	Not used	2	54.5	2.9	4.78	2	33.2	5	24
AN0207	Pascack Bk	7/1/03	Verification	3	40.0	4.0	5.31	3	40.5	5	18
AN0192	Rahway River	10/13/04	**Calibration**	0	55.6	0.0	8.05	1	8.3	5	9
AN0194	Rahway River	10/13/04	**Calibration**	1	70.0	0.0	6.37	1	14.7	5	9
AN0195	Rahway River	10/21/04	Not used	3	58.3	1.8	4.39	4	43.0	5	18
HW51	Rahway River	7/19/03	Verification	2	37.5	9.9	5.88	0	22.9	5	12
AN0267	Ramapo River	7/10/90	Not used	4	53.3	12.1	5.77	3	22.8	5	18
AN0267	Ramapo River	8/7/98	**Calibration**	7	33.3	29.4	4.49	3	43.4	4	30
AN0267	Ramapo River	10/21/03	Not used	6	33.3	27.5	4.27	4	45.5	4	30
AN0199	Robinsons Br	10/21/04	Verification	1	50.0	0.0	4.74	2	31.4	5.5	15
AN0412	Royce Bk Br	9/30/04	Verification	2	61.5	1.0	4.63	2	24.0	5	12

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0279	Saddle R	7/17/90	Not used	6	20.0	17.9	3.96	5	65.0	5	30
AN0279	Saddle R	8/14/98	Not used	4	28.6	4.8	4.44	4	49.3	5	24
AN0279	Saddle R	7/8/03	**Calibration**	5	44.4	28.0	5.21	3	45.7	4	21
AN0281	Saddle R	7/17/90	Not used	6	35.3	6.1	5.18	3	46.5	5	24
AN0281	Saddle R	8/13/98	Not used	6	36.8	8.1	5.20	6	56.5	5	24
AN0281	Saddle R	7/10/03	Not used	5	28.6	13.6	5.48	2	44.4	5	18
AN0282	Saddle R	7/17/90	Not used	3	33.3	4.5	4.62	5	52.2	5	24
AN0282	Saddle R	8/14/98	**Calibration**	3	40.0	1.8	4.64	4	45.9	5	24
AN0282	Saddle R	10/28/03	Not used	3	36.4	5.6	4.19	2	43.7	5	24
AN0289	Saddle R	7/17/90	Not used	1	44.4	0.0	4.99	1	30.8	5	18
AN0289	Saddle R	8/18/98	Not used	1	70.0	0.0	6.09	2	20.5	5	12
AN0289	Saddle R	10/28/03	Not used	1	50.0	0.0	4.92	1	29.4	5	15
AN0290	Saddle R	7/17/90	Not used	1	50.0	0.0	6.55	0	18.5	5	12
AN0290	Saddle R	8/18/98	Not used	2	40.0	0.9	6.76	0	22.5	5	9
AN0291	Saddle R	7/17/90	Not used	1	62.5	0.0	7.31	0	11.0	5	3
AN0291	Saddle R	8/18/98	Not used	3	66.7	25.2	5.88	3	37.7	5	21
AN0435	Sawmill Bk	9/30/93	Not used	1	64.7	0.0	7.17	2	10.3	5	12
AN0435	Sawmill Bk	9/10/98	Not used	1	55.6	0.9	7.89	3	16.8	5	12
AN0435	Sawmill Bk	7/29/04	**Calibration**	0	75.0	0.0	8.33	2	7.0	5	9
AN0293	Second River	6/24/04	**Calibration**	2	44.4	7.8	7.76	1	19.0	5	9
HW52	Second River	7/19/03	**Calibration**	0	42.9	0.0	6.32	0	11.6	5	6
AN0200	South Br Rahway River	10/7/04	**Calibration**	1	61.5	0.0	4.70	2	21.0	5	18
AN0201	South Br Rahway River	8/9/01	Not used	3	41.7	2.4	5.90	2	29.8	5	12
AN0201	South Br Rahway River	6/12/02	**Calibration**	2	55.6	7.4	7.46	1	15.1	5	9
AN0201	South Br Rahway River	10/5/04	Not used	2	50.0	1.0	4.63	2	31.5	5	18
AN0209	Tenakill Bk	7/6/93	Not used	0	66.7	0.0	6.27	0	7.7	5	6
AN0209	Tenakill Bk	7/9/98	Not used	0	87.5	0.0	8.21	0	1.6	5	6
AN0209	Tenakill Bk	7/1/03	**Calibration**	0	76.9	0.0	6.59	2	11.7	5	15

Station	Waterbody Name	CollDate	CalVer	EPTFam	NonInsFam PT	EPTnHPct	HBI_Fam	ScrapFam	HGMIfam	BCG Tier	NJIS
AN0292	Third River	7/6/93	Not used	2	54.5	5.0	4.50	4	39.5	5	21
AN0292	Third River	8/19/98	**Calibration**	2	66.7	5.4	4.42	1	26.2	5	21
AN0292A	Third River	9/25/98	**Calibration**	1	83.3	0.0	4.79	2	20.8	5	12
HW53	Third River	7/17/03	**Calibration**	3	50.0	2.1	5.24	2	28.9	4	15
HW54	UNT to Passaic River	7/28/03	**Calibration**	2	33.3	2.0	6.01	1	24.0	4	6
AN0197	UNT to Robinsons Br	10/7/04	**Calibration**	1	58.3	0.0	4.41	2	24.4	5	18
AN0198	UNT to Robinsons Br	10/7/04	**Calibration**	0	70.0	0.0	7.35	2	6.7	5	9
AN0110	UNT to Shipetaukin Ck	6/3/03	**Calibration**	1	64.3	0.8	6.81	3	13.5	5	15
AN0284	Valentine Bk	7/16/90	Not used	1	53.8	0.0	5.57	1	17.0	5	15
AN0284	Valentine Bk	8/13/98	Not used	1	50.0	0.0	5.28	2	23.1	5	12
AN0284	Valentine Bk	8/21/01	Not used	1	62.5	0.0	4.52	2	22.9	5	18
AN0284	Valentine Bk	6/5/02	Not used	0	66.7	0.0	6.05	1	8.9	5.5	6
AN0284	Valentine Bk	7/30/03	**Calibration**	1	46.2	0.0	5.79	2	21.7	5	15
AN0211	Van Saun Bk	7/6/93	Not used	1	55.6	0.0	6.51	0	10.6	5	12
AN0211	Van Saun Bk	7/10/98	Not used	1	77.8	0.0	6.09	2	14.7	5	9
AN0211	Van Saun Bk	7/8/03	**Calibration**	1	72.7	0.0	6.87	0	4.2	5	12
AN0280	W Br Saddle River	7/17/90	Not used	7	13.3	9.3	3.89	5	63.3	4	27
AN0280	W Br Saddle River	8/14/98	Not used	4	30.0	12.4	5.07	4	44.6	4	18
AN0280	W Br Saddle River	7/8/03	**Calibration**	4	44.4	32.0	5.60	4	43.3	4	24
AN0202	West Br Elizabeth River	9/16/98	Not used	0	80.0	0.0	7.06	0	0.0	5	9
HW55	West Br Elizabeth River	7/2/03	**Calibration**	0	42.9	0.0	6.47	1	14.5	5	9
HW56	West Br of Shabakunk Creek	7/29/03	Verification	3	33.3	2.0	5.30	2	31.7	5	15