DEVELOPMENT OF REGIONALLY-BASED NUMERIC INTERPRETATIONS OF TENNESSEE'S NARRATIVE BIOLOGICAL INTEGRITY CRITERION

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L & C Annex
401 Church Street
Nashville, TN 37243-1534

Development of Regionally-Based Numeric Interpretations of Tennessee's Narrative Biological Integrity Criterion

A Criteria Development Document

Prepared for the

Tennessee Water Quality Control Board

by

Deborah H. Arnwine

Gregory M. Denton

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Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L & C Annex
401 Church Street
Nashville, TN 37243-1534

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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LIST OF REVIEWERS

United States EPA

James E. Harrison
Environmental Scientist
EPA Region IV, Water Quality Standards
100 Alabama Street, N.W.
Atlanta, Georgia 30303

Hoke S. Howard
Aquatic Biologist, EPA Region IV,
Science & Ecosystem Support Division
980 College Station Road
Athens, Georgia 30605

EPA Region IV States

Vickie Hulcher
Environmental Scientist
Alabama Department of Environmental Management
1890 Cong. W.L. Dickinson Drive
Montgomery, AL 36109

Greg Pond
Principal Environmental Biologist
Kentucky Division of Water
14 Reilly Road
Frankfurt, Kentucky 40601

Environmental Consultants

Michael T. Barbour
Director, Ecological Services
Tetra Tech, Inc.
10045 Red Run Blvd., Suite 110
Owings Mill, MD 21117

Chris Yoder
Senior Research Associate
Midwest Biodiversity Institute
P.O. Box 21561
Columbus, Ohio 43221-0561

Tennessee Valley Authority

Charles Saylor
Fisheries Biologist
TVA Aquatic Biology Laboratory
Norris, TN 37828

Tennessee Department of Environment and Conservation

Chad Augustin
Biologist, Water Pollution Control
Columbia Environmental Assistance Center
2484 Park Plus Drive
Columbia, Tennessee 38401

Jonathon Burr
Biologist, Water Pollution Control
Knoxville Environmental Assistance Center
2700 Middlebrook Pike
Knoxville, Tennessee 37921

Melanie Catania
Environmental Policy Office
L&C Tower, 401 Church Street
Nashville, TN 37423

Paul Davis (Director)
Garland Wiggins (Assistant Director)
Water Pollution Control Central Office
L&C Annex, 401 Church Street
Nashville, TN 37243-1534

Joe Holland
Manager, Water Pollution Control
Nashville Environmental Assistance Center
711 R.S. Gass Boulevard
Nashville, Tennessee 37243

Pat Patrick (Manager)
Amy Fritz (Biologist)
Water Pollution Control
Jackson Environmental Assistance Center
362 Carriage House Drive
Jackson, Tennessee 38305-2222

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Additionally, EPA facilitated the participation of Michael Barbour and Chris Yoder as formal peer reviewers for this document. The authors acknowledge the contributions of Dr. Barbour and Mr. Yoder to the report development process. Anyone wishing to receive a copy of the Division's responses to the formal review comments should contact the authors.

The staff of the Department's regional environmental assistance centers (EACs) selected the reference sites and collected most of the data documented in this report. The managers of the Water Pollution Control staff in these offices are:

Phil Stewart	Chattanooga EAC
Pat Patrick	Jackson EAC
Andrew Tolley	Johnson City EAC
Paul Schmierbach	Knoxville EAC
Terry Templeton	Memphis EAC
Joe Holland	Nashville EAC

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EXECUTIVE SUMMARY

According to the Division's 2000 305(b) report, a significant number of stream miles in Tennessee are impaired by pollutants which have criteria based on narrative statements. The existing water quality standards provide limited guidance concerning how these narrative statements should be applied. Tennessee's current narrative biological criterion found in chapter 1200-4-3-03(3)(j) of the water quality standards states, in part, that "Waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or adversely affected…" The terms "substantially" and "adversely" are not defined.

Additionally, the existing criterion states that the condition of the biological communities will be measured by the use of metrics, but does not specify what metrics are to be used. Since different metrics measure different aspects of the biological community and have different levels of sensitivity to pollution, application of the current criterion relies heavily on which metrics are selected and individual interpretations of stream health. A more standardized measurement calibrated to specific bioregions is needed to effectively assess biological integrity in a consistent and fair manner.

The purpose of this study was to develop guidance for interpretation of biological data based on regional reference data collected in least impaired, yet representative, streams in each of 25 ecological subregions across the state. An ecoregion is a relatively homogenous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, and other ecologically relevant variables. Ninety-eight reference streams were monitored seasonally between 1996 and 2001. Data from these reference systems provided a scientifically defensible method for regional interpretations of the existing statewide narrative criterion for biological integrity. The Division is recommending these interpretations be formalized in the General Water Quality Criteria.

In addition to the standard Division review process, this document has undergone extensive EPA and other professional peer review. Water quality biologists from the seven sister states in EPA Region IV were invited to comment. Two states, Kentucky and Alabama, currently in the process of regional delineation and reference stream determination provided many useful comments that helped refine this proposal. In addition, EPA helped arrange for two experts in the field of biocriteria development to review this document. The comments from reviewers helped make this document more defensible.

Reference biological data used in this proposal consisted of single habitat semi-quantitative samples of the macroinvertebrate community. The advantages of using macroinvertebrates as water quality indicators include their sensitivity to various types of chemical pollution, dependency on stable habitat, limited mobility, diversity and vital position in the food chain. The single habitat semi-quantitative sample method is easily standardized and has been found to yield consistent results. Two different sample methods were used dependent on the most prevalent stream type in each subregion.

After analyses of the reference data, a biological index based on multiple metrics was developed to measure the health of the macroinvertebrate community. Multiple metrics are a widely accepted method to assess the health of the stream biota. It is not uncommon for one attribute of the aquatic community to change in response to impact while others remain unchanged. This necessitates the use of several metrics, each representing a different aspect of the benthic community. The Division evaluated 11 potential metrics from four distinct categories (richness, composition, tolerance and trophic state) to develop biocriteria that reflected various aspects of the whole macroinvertebrate community. Seven metrics were selected to create an index for criteria development. Metrics were targeted that measured multiple components of the benthic population and assessed different types of pollution and/or habitat alteration.

After appropriate biometrics were selected, they were used to compare the reference stream benthic population between each of the 25 ecological subregions found in Tennessee. Where the differences between ecological subregions were not significant based on multivariate analysis, subregions were grouped into bioregions. (For this study, a bioregion is defined as an ecological subregion or group of subregions that has a distinct macroinvertebrate community for assessment purposes.) In subregions where the biological communities were significantly different, the individual subregion was treated as a bioregion. Fifteen bioregions, each with distinct macroinvertebrate communities, were defined in Tennessee. Different biocriteria limits based on the same seven metrics were proposed for each bioregion.

Once bioregions were established, the data were tested to determine if there were seasonal differences among the biometrics being used to measure the macroinvertebrate community. Seasonal variability was observed in seven bioregions. Separate biocriteria were proposed based on season in these bioregions. In addition, one bioregion (71i - Inner Nashville Basin) had separate criteria based on stream type (riffle/run or glide/pool) since both stream types are prevalent in this region.

After bioregions and seasonal variability were determined, expected ranges for the seven selected biometrics within each bioregion were calculated. This was done by quadrisecting the data at the 10^{th} or 90^{th} percentile depending on whether the metric was expected to increase or decrease with perturbation. This allowed the metrics to be equalized by assigning a value depending on quadrant. After metrics were equalized, they were combined into a single multi-metric index. Index scores were calibrated by bioregion using reference data. Biocriteria were set at 75 percent of the maximum possible index score for each bioregion. This method set a goal that accommodates uncertainty and promotes attainability for non-reference streams.

After metric ranges and target index scores were developed based on reference data, it was necessary to field test the proposed criteria to ensure that it was a fair and accurate method for assessing the health of the benthic community. This was done in three stages: First the proposed method, as well as two alternative methods, were tested against historic assessments at 60 sites in 10 bioregions. The proposed quadrisected method of establishing biocriteria proved to be the most responsive to impairment of the three methods tested without being overly sensitive. Biological assessments based on the proposed quadrisected index matched the original assessment of biotic integrity at 84 percent of the stations.

Next, the proposed regional reference-based biocriteria were compared to both impaired and unimpaired test sites in six bioregions. The proposed biocriteria proved to be sensitive to moderate and high levels of pollution but did not indicate impairment when sites has been assessed as supporting a healthy benthic community. The proposed method also proved useful in defining the level of impairment in studies that had inconclusive findings due to impaired upstream reaches.

Finally, probabilistic monitoring data at fifty randomly selected streams in the Inner Nashville Basin were compared to the proposed biocriteria. Results were consistent with non-random watershed assessments within this region.

The biocriteria indices should only be applied to streams that are similar to those in the reference stream database for each subregion. To insure similarity, the drainage upstream of a study site must be entirely or mostly (80%) within a bioregion. The stream should be similar in size to those used in the study (this varies by bioregion). The proposed biocriteria would not be appropriate for use in lakes and reservoirs, wetlands or large rivers. It should only be used to assess first order streams in those regions where first order reference streams were targeted for monitoring.

These criteria are based on single habitat, semi-quantitative macroinvertebrate samples. The same sample method and habitat type must be collected at study sites for comparison to criteria. All criteria were developed using a 200-organism subsample identified to the genus level. Different sampling techniques, subsamples that are larger or smaller, as well as samples identified to different taxonomic levels, such as family or species, would not be comparable.

Seasonal differences were significant in some regions. Criteria were adjusted for seasonality in these regions. The appropriate index should be used based on the month sampled within these regions.

Regional interpretations of the narrative criteria should be used primarily for assessment purposes. Once established, the use of regional biocriteria will help standardize Division biological assessments and will account for regional differences in expected aquatic communities. As an additional benefit, standardized biocriteria based on regional reference data will decrease the need for reference or upstream monitoring during water quality investigations thus reducing monitoring time and costs.

Existing reference sites will be monitored in the future on a five-year rotation in conjunction with watershed monitoring. Should future watershed monitoring activities or ecoregion efforts in nearby states uncover additional reference quality streams, these data will be used to augment the existing databases. As appropriate, biocriteria can be adjusted in future triennial reviews as more data becomes available.

1. INTRODUCTION

Biological criteria or "biocriteria" are used to define expected biological conditions. Biocriteria are numeric values or narrative descriptions that describe the reference biological integrity of aquatic communities (Bode and Novak, 1995). The health of the benthic community is an important indicator of disturbances in the watershed. Biological communities are indicative of actual conditions because they inhabit the stream continuously and are subject to the various chemical and physical influences that occur over time. Loss of biological integrity is often the result of environmental impacts such as habitat destruction, siltation, flow alteration, organic enrichment, reduced dissolved oxygen, pH fluctuations and elevated metals.

Tennessee's current biological criterion is narrative. Found in chapter 1200-4-3-03(3)(j), the rule states in part that "Waters shall not be modified through the addition of pollutants or through physical alteration to the extent that the diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or adversely affected…" The terms "substantially" and "adversely" are not defined.

Additionally, the existing criterion states that the condition of the biological communities will be measured by the use of metrics, but does not specify what metrics are to be used. Since different metrics measure different aspects of the biological community and have different levels of sensitivity to pollution, application of the current criterion relies heavily on which metrics are selected and individual interpretations of stream health. A more standardized measurement calibrated to specific bioregions is needed to effectively assess biological integrity in a consistent and fair manner.

Objectives for the development of numeric biocriteria include:

1. Selecting methods that are scientifically sound and defensible, resulting in conclusions that indicate impairment in cases where it is justified but do not assign impairment in cases where the biological change is minor or questionable.

2. Basing criteria on indices that are simple and understandable in terms of the biological health of the stream so that assessments are meaningful to non-biologists including the general public.

3. Establishing criteria that measure multiple components of the benthic community so that all organisms are protected.

4. Defining criteria that are responsive to various types of pollution including toxicity, enrichment, sedimentation and habitat alteration.

2. DATA COLLECTION

A method was needed for comparing the existing conditions found in a stream to relatively unimpaired streams. This "reference condition" needed to be established within a similar area, to avoid inappropriate comparisons. Ecoregions appeared to be the best geographic basis upon which to make this assessment. An ecoregion is a relatively homogenous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, and other ecologically relevant variables.

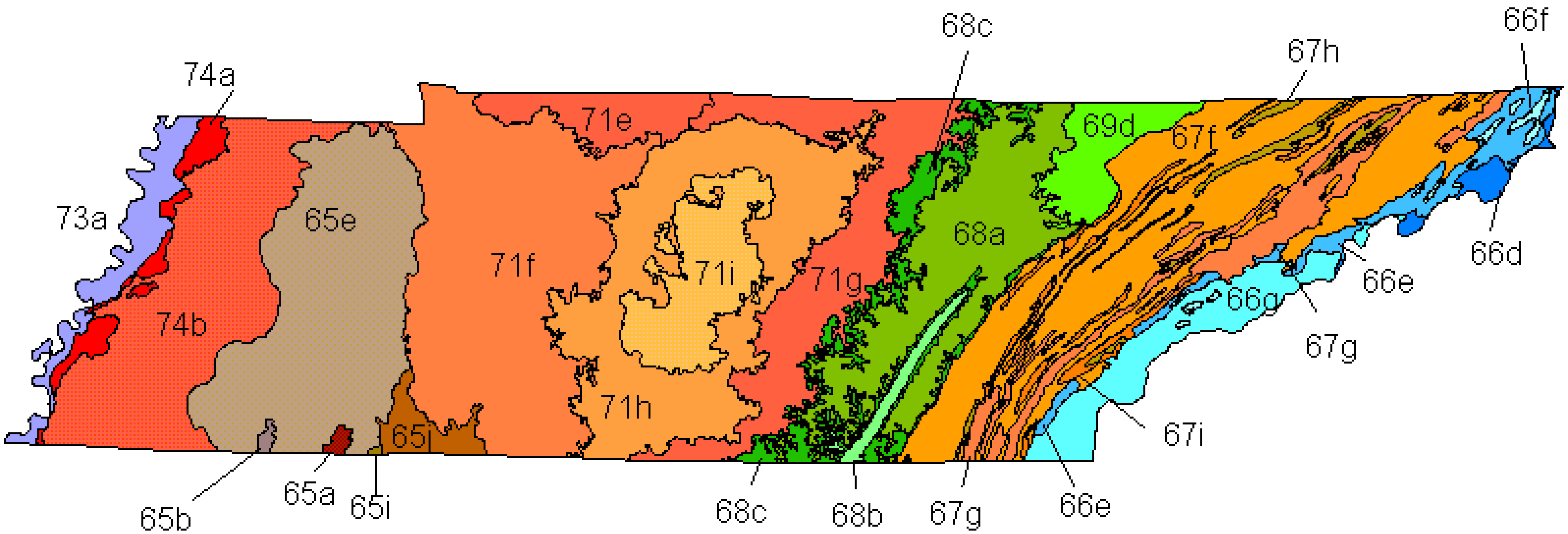
In order to delineate ecoregions and isolate reference streams, the Division of Water Pollution Control initiated the Tennessee ecoregion project that began in 1993 and concluded in 1999. Details of that project including delineation of ecoregion boundaries, descriptions of subregions, reference stream selection and monitoring protocols as well as data summaries can be found in the Division's Ecoregion Project report (Arnwine et al, 2000). The data generated from the reference streams monitored during this study were used in regional biocriteria development.

2.0 Delineation of Ecological Subregions

The "Ecoregions of the United States" map (Level III) developed in 1986 by James Omernik of EPA's Corvalis Laboratory delineated eight major ecoregions in Tennessee. Due to the high diversity and complexity of these ecoregions, it was necessary to refine and subdivide the ecoregions into smaller subregions before reference streams could be selected. Beginning in 1993, the Division arranged for James Omernik and Glenn Griffith to subregionalize and update the ecoregions.

During the delineation process, maps containing information on bedrock and surface geology, soil, hydrology, physiography, topography, precipitation, land use and vegetation were reviewed. Interagency cooperation widened the base of maps, information and resources available to delineate subregions. Much of this information was digitized to produce draft maps of ecoregion and subregion boundaries.

Multiple agencies were invited and represented at one of three ecoregion meetings held during 1994 - 95. Attendees included aquatic biologists, ecologists, foresters, chemists, geographers, engineers, university professors and regulatory personnel from 27 state and federal agencies as well as universities and private organizations. The judgment of these experts was applied throughout the selection, analysis and classification of data to determine the final ecoregion and subregion boundaries in Tennessee. A summary of ecoregion and subregion characteristics is included in Appendix A. A more detailed description of the delineation process and of all Level III and Level IV ecoregions can be found in the Ecoregions of Tennessee report (Griffith, 1997). A map illustrating ecological subregion boundaries in Tennessee is presented in Figure 1.



65a Blackland Prairie
65b Flatwoods/Alluvial Prairie Margins
65e Southeastern Plains and Hills
65i Fall Line Hills
65j Transition Hills
66d Southern Igneous Ridges and Mtns
66e Southern Sedimentary Ridges
66f Limestone Valleys and Coves
66g Southern Metasedimentary Mountains
67f Southern Limestone/Dolomite Valleys and Low Rolling Hills
67g Southern Shale Valleys
67h Southern Sandstone Ridges
67i Southern Dissected Ridges & Knobs
68a Cumberland Plateau
68b Sequatchie Valley
68c Plateau Escarpment
69d Cumberland Mountains
71e Western Pennyroyal Karst
71f Western Highland Rim
71g Eastern Highland Rim
71h Outer Nashville Basin
71i Inner Nashville Basin
73a Northern Mississippi Alluvial Plain
74a Bluff Hills
74b Loess Plains

Figure 1: Level IV Ecoregions of Tennessee

2.1 Reference Stream Selection

Three hundred and fifty-three potential reference sites were evaluated as part of the ecoregion project. The reference sites were chosen to represent the best attainable conditions for all streams with similar characteristics in a given subregion. Reference condition represented a set of expectations for physical habitat, general water quality and the health of biological communities in the absence of human disturbance and pollution. Selection criteria for reference sites included minimal impairment and representativeness. Streams that did not flow across subregions were targeted so the distinctive characteristics of each subregion could be identified.

Site evaluation required field visits by experienced biologists to screen each candidate reference stream. Abbreviated screenings of the benthic community, focusing on clean water indicators, were conducted at each potential site. Measurements of dissolved oxygen, pH, conductivity and water temperature were taken. Habitat assessments were also conducted. The upstream watershed was investigated for potential impacts. Potential sites were rated as to how well they met the following criteria:

a. The entire upstream watershed was contained within the subregion.
b. The upstream watershed was mostly or completely forested (if forest was the natural vegetation type) or had a typical land use for the subregion.
c. The geologic structure and soil pattern was typical of the region.
d. The upstream watershed did not contain a municipality, mining area, permitted discharger or any other obvious potential sources of pollutants, including non-regulated sources.
e. The upstream watershed was not heavily impacted by nonpoint source pollution.
f. The stream flowed in its natural channel and had not been recently channelized. There were no flow or water level modification structures such as dams, irrigation canals or field drains.
g. No power or pipelines crossed upstream of the site.
h. The upstream watershed contained few roads.

Originally, three reference streams per subregion were considered the minimum necessary for statistical validity. Only two streams could be found in smaller subregions. Seventy streams were targeted for intensive monitoring beginning in 1996. After analysis of the first year's data, it was determined that a minimum of five streams per subregion would be more appropriate (Barbour and White, 1998). Where possible, additional reference streams were added. However, in smaller subregions or those with widespread human impact this was not possible. Forty-four reference streams were added to the study resulting in intensive monitoring at 114 sites beginning in fall 1997. By the end of the project, there were between two and eight reference streams targeted in each subregion.

2.2 Biological Monitoring

Macroinvertebrates were selected as the indicator organisms to determine the health of the biotic community in streams in each subregion throughout the state. The advantages of using macroinvertebrates as water quality indicators are their:

a. Sensitivity to various types of chemical pollution.
b. Sensitivity to physical changes in the stream environment.
c. Dependency on stable habitat.
d. Limited mobility to avoid sources of pollution.
e. Responsiveness to intermittent discharges.
f. Abundance and diversity.
g. Ease of collection.
h. Vital position in the food chain.

Semi-Quantitative collection methods, sample processing and taxonomic methodology are detailed in the 1996 Tennessee standard operating procedure for freshwater aquatic macroinvertebrates (TDEC 1996). A 200 (+/- 20%) organism subsample was analyzed. Subsampling protocols are presented in Section 7.3 of EPA's Rapid Bioassessment Protocols (Barbour et al. 1999). A draft version of this protocol was used prior to 1999. Taxa were identified to the genus level. These specific collection methods, subsampling protocols and taxonomic levels must be used when directly applying the criteria to ensure comparability.

2.2.0 <u>Field Collections</u>

Sampling at the reference sites began August 1996. Collections were planned to coincide with low flow (mid-August to mid-October) and high flow (mid-March to mid-May) periods to capture possible seasonal changes in the benthic community. Six consecutive sampling events occurred over the first three years resulting in three spring and three fall collections by spring 1999. Monitoring of reference sites since 1999 has taken place in conjunction with the 5-year watershed monitoring cycle.

Staff involved in biological sampling had experience and training in stream survey work including macroinvertebrate collection and identification methods. Single habitat semi-quantitative collection techniques (TNSOP 1996 and Barbour et al, 1999) were used to define biocriteria. Qualitative habitat samples were also collected the first year but were not used for biocriteria due to inconsistency in sampling technique. Use of a single habitat provides a more easily standardized sample that focuses on the most productive habitat in the stream. This type of sampling targets the richest and most diverse components of the macrobenthos that include a variety of sensitive and tolerant organisms.

The habitat sampled was based on the dominant stream type in each subregion. In streams containing riffle areas, two riffle kicks were collected using a one square meter, 500-micron mesh kick net. One kick was collected in fast moving water and a second kick was collected from slower moving water. The two kick samples were composited and preserved in the field.

In non-riffle streams, semi-quantitative samples were collected with a 500-micron mesh A-frame dip net. Three 1 meter sweeps were collected from different areas of rooted undercut bank, composited and preserved in the field. All samples were sent to the state lab for sorting and identification.

2.2.1 Sample Processing and Identification

All macroinvertebrate samples were processed by experienced taxonomists at the central laboratory facility. Use of a centralized group ensured consistency, accuracy and efficiency in sorting, subsampling, identification, data entry and data reduction efforts. A 200 organism subsample was identified to the genus level. Biocriteria were developed at this taxonomic level. The 200 organism subsample provided the greatest number of taxa for the least amount of effort. Genus level identifications were chosen over species level because of:

1. Time/personnel constraints
2. Consistency of identifications
3. Keys are not available for species identification of all taxa, therefore some metrics may be skewed by varying identification levels of different groups.
4. Widespread use in water quality assessments
5. Maturity of specimens – many organisms are early instars making species determinations impractical.

2.2.2 Quality Assurance

Stringent quality assurance protocols were used to ensure accuracy and consistency in characterization of the reference stream community structure. Ten percent of all samples were re-sorted by a second taxonomist. All staff maintained a minimum 90 percent sorting efficiency. Ten percent of all samples were re-identified by a second taxonomist. A 95 percent accuracy rate was maintained. Voucher collections containing representatives of all taxa found in that subregion were made for each of the 25 subregions. A master reference collection containing a representative of each taxon collected during the study was also created. All taxa in the master reference collection were sent to outside experts for verification.

3. METRIC SELECTION

Biometrics were selected to numerically interpret the health of the benthic community. A biometric is a calculated value representing some aspect of the biological population's structure, function or other measurable characteristic that changes in a predictable way with increased human influence (Barbour et al, 1999). For a metric to be considered useful, it must:

a. Be ecologically relevant to the biological assemblage
b. Pertain to the specified program objectives
c. Demonstrate sensitivity to environmental stressors
d. Provide a response that can be discriminated from natural variation

There are three common approaches when using biometrics to measure the health of the benthic community:

1. Use a single metric.
2. Apply multiple metrics independently.
3. Combine multiple metrics into a single index.

Different pollutants affect the benthic community in different ways. Due to the broad range of possible impacts, the use of multiple metrics either applied independently or as part of an index is the most comprehensive method to assess the health of the entire benthic community. This strategy has been adopted by many states for criteria development and assessment protocols. The strength of using multiple metrics is to integrate information from the individual, population, community and ecosystem levels. Using more than one metric also insures that the effects of different types of pollutants are measured.

A **single metric** can be misleading, since metrics respond differently to various stressors and represent different aspects of the benthic community. It is not uncommon for one metric to change in response to impact while others remain unchanged. For example the abundance of EPT taxa, a metric that is generally considered indicative of a healthy stream, may be high due to the presence of one or two nutrient tolerant taxa such as *Stenonema* spp. or *Cheumatopsyche* spp. However, the dominance of these two EPT genera would create a higher tolerance index (NCBI) indicating a stressed community. Therefore, if only one metric (% EPT) were used, the stream would have been assessed as non-impaired when it actually had elevated organic enrichment. Only by using several different metrics can a clear picture of the benthic community health be achieved.

Initially, the Division tested a multi-metric approach based on **four metrics independently applied** that would measure different aspects of the benthic community. This method proved overly sensitive. When applied to randomly selected streams in ecoregion 71i, only 22 percent of the streams met the test criteria. This approach also consistently rated streams as having higher levels of impacts than historic assessments in other regions. Using this method, only 21 percent of streams previously assessed as supporting aquatic life would pass criteria.

After testing these other options, the Division determined that a **multi-metric index** was the most comprehensive and unbiased method for establishing criteria to assess the macroinvertebrate community. The index proved responsive to various pollution sources without being overly sensitive to natural variation.

Eleven biometrics were evaluated to determine which would be included in the index (Table 1). These metrics included seven that were proposed for a Tennessee Stream Condition Index after an evaluation of 19 biometrics based on the first year of ecoregion data by Barbour and White (1998). All of the metrics being considered for criteria development had historically been used by the Division to evaluate benthic populations. The metrics under consideration represented the following four assessment categories:

1. **Richness** metrics measure the diversity or variety of the benthic community. High richness values indicate that habitat and food sources are adequate to support the survival and reproduction of many taxa.

2. **Composition** metrics measure taxa identity and dominance. These metrics provide information on the relative contribution of a group of taxa to the population as a whole. A healthy and stable macroinvertebrate community should be relatively consistent in the proportion of various taxa groups.

3. **Tolerance** metrics are a direct measure of sensitivity to pollution. A healthy macroinvertebrate community will have taxa representing all tolerance levels. The relative abundance of tolerant organisms increases with increased pollution.

4. **Habit and Feeding** metrics measure trophic interaction and food source availability. Organisms that have specialized feeding or habitat requirements are more sensitive and should be well represented in healthy streams.

The most responsive metrics from each category were selected to measure the overall health of the macroinvertebrate community. The original goal was to select two metrics from each category, however only one metric in the habit/feeding category proved responsive. Metrics were chosen based on accuracy, low variability and simplicity. Each represented a different aspect of the benthic community. The goal was to develop biocriteria that reflected various aspects of the macroinvertebrate community and were responsive to different types of environmental disturbance.

Table 1: Biometrics evaluated as candidates for biological criteria.

Category	Metric	Definition	Expected Response to Stress
Richness Measures	Taxa Richness	Measures the overall variety of the macroinvertebrate assemblage.	Decrease
	EPT Richness	Number of taxa in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).	Decrease
Composition Measures	% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae.	Decrease
	% Chironomidae	Percent of midge larvae.	Increase
	% OC	Percent of the composite of Oligochaeta (aquatic worms) and Chironomidae (midge larvae).	Increase
Tolerance Measures	NCBI	North Carolina Biotic Index – Uses tolerance values to weight abundance in an estimate of overall pollution.	Increase
	% Dominant Taxon	Measures dominance of the single most abundant taxon.	Increase
	% Tolerant Organisms	Percent of macrobenthos considered to be tolerant of various types of environmental stress.	Increase
Habit/Feeding Measures	% Clingers	Percent of benthos having fixed retreats or adaptations for attachment to surfaces.	Decrease
	% Predators	Percent of the predator functional feeding group.	Increase
	% Shredders	Percent of macrobenthos that shred leaf litter.	Decrease

Adapted from EPA 841-B-99-002 Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers

Each of the candidate metrics was evaluated using box and whisker plots to determine if the metric was sensitive to differences in the benthic community at reference stations between ecoregions (Figures 2 through 5).

A box plot is a graph that displays the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles of a variable. The plot is composed of a central box divided by a line, and two lines extending out from the box called whiskers. The length of the box indicates the distribution of the middle 50% of the data. The lower and upper hinges of the box mark the 25^{th} and 75^{th} quartiles of the data respectively. The line through the box represents the sample median. Boxes in which the median does not fall near the middle of the box represents skewed data. The whiskers represent the 10^{th} and 90^{th} percentiles. Whisker length corresponds to the spread of the data. Outliers are points that fall outside of the 90^{th} (10^{th}) percentile. Outliers are a common occurrence in any data set.

Box plots are useful because they allow direct side-by-side comparison of data from several groups within a single figure. Each box plot graphically illustrates the central tendency (median; center of the data), variability (interquartile range; spread of the middle 50% of the data), minimum and maximum values (the full range) of a data set as a single icon. The relationship between the data sets is shown by the amount of overlap of the median and interquartile between box plots.

Candidate metrics were evaluated at both the ecoregion level and between sites. Metrics with low values in reference condition and metrics that had high variability within reference sites were eliminated from consideration. These metrics would not be able to adequately discriminate between impaired and unimpaired sites.

For Figures 2 through 5, N is equal to the number of samples while Sites refer to the actual number of reference sites.

Ecoregion 65; N = 68, Sites = 14
Ecoregion 66; N = 68, Sites = 19
Ecoregion 67; N = 62, Sites = 18
Ecoregion 68; N = 58, Sites = 15
Ecoregion 69; N = 21, Sites = 5
Ecoregion 71; N = 81, Sites = 20
Ecoregion 73; N = 16, Sites = 4
Ecoregion 74; N = 33, Sites = 3

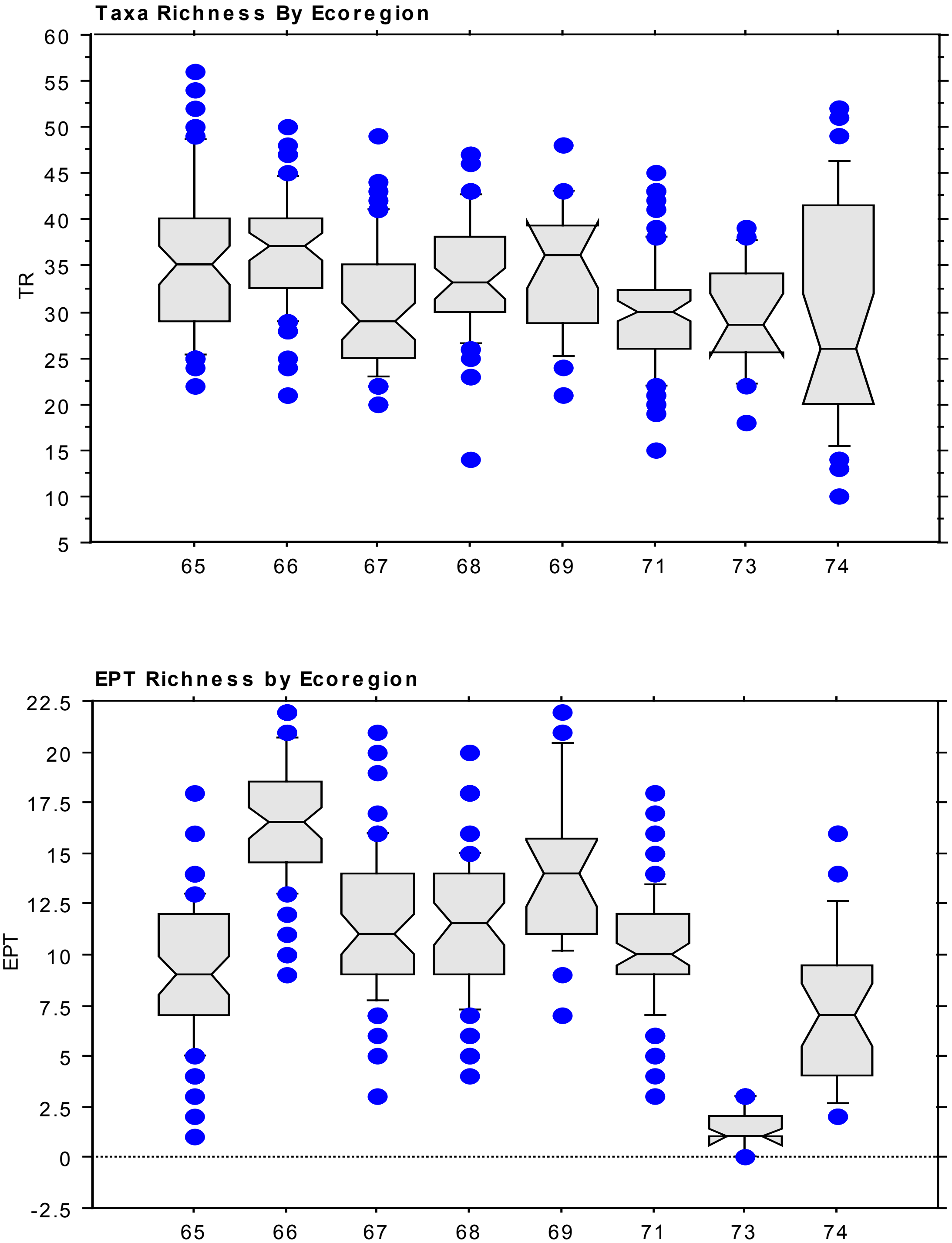


Figure 2: Range in richness metrics for reference sites by ecoregion. Multiple sampling events at reference sites are included.

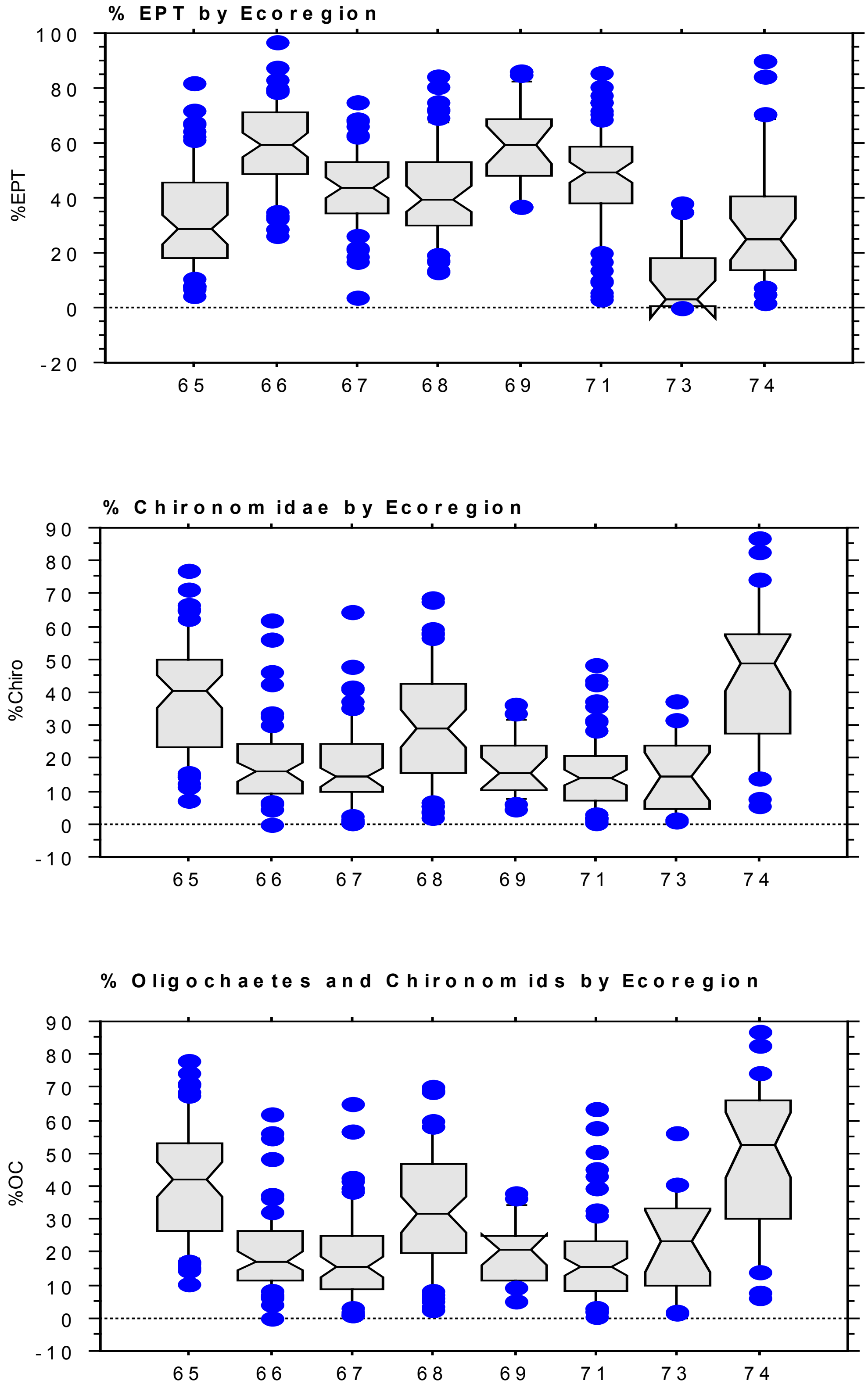


Figure 3: Range in composition metrics for reference sites by ecoregion. Multiple sampling events at reference sites are included.

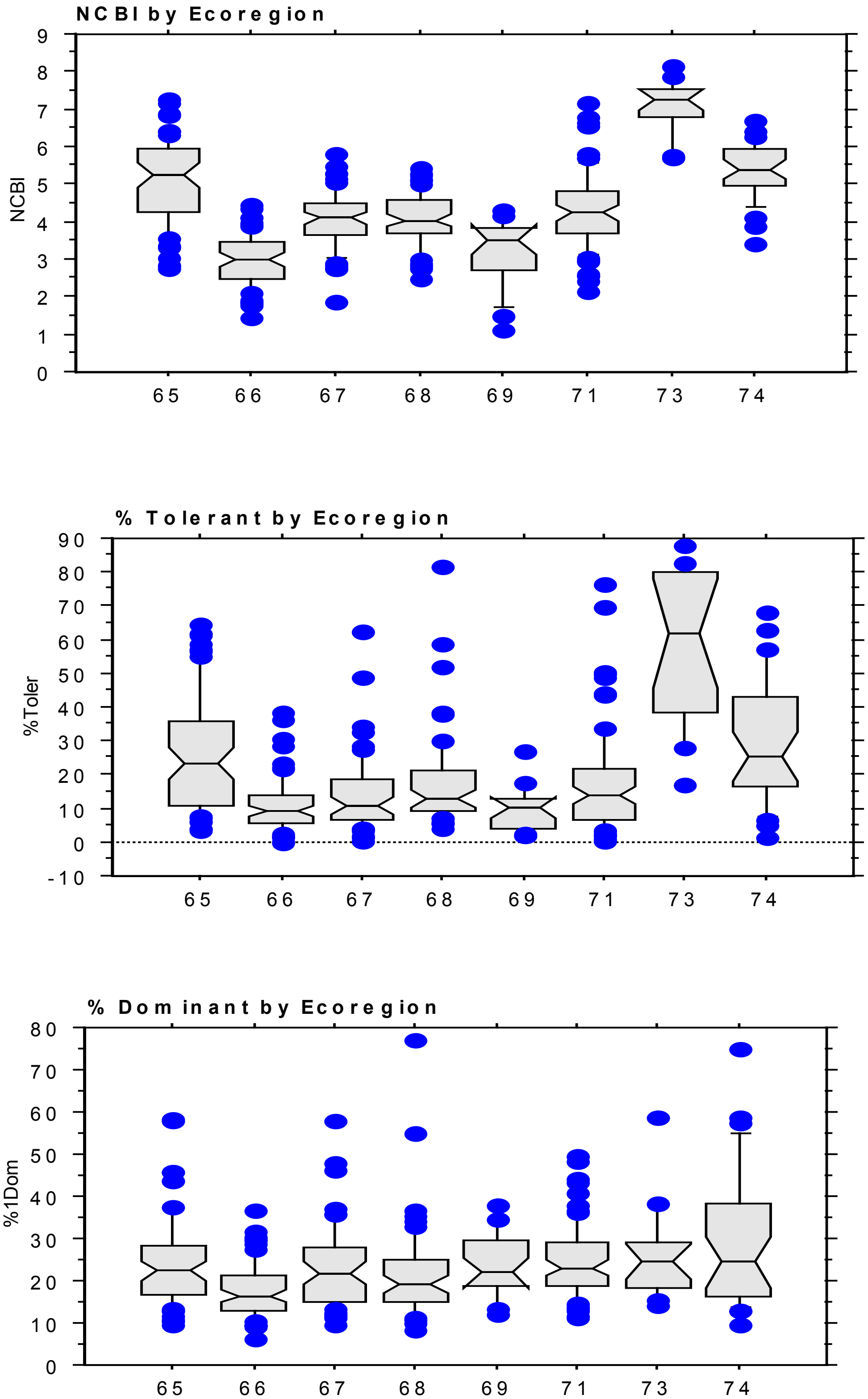


Figure 4: Range in tolerance metrics for reference sites by ecoregion. Multiple sampling events at reference sites are included.

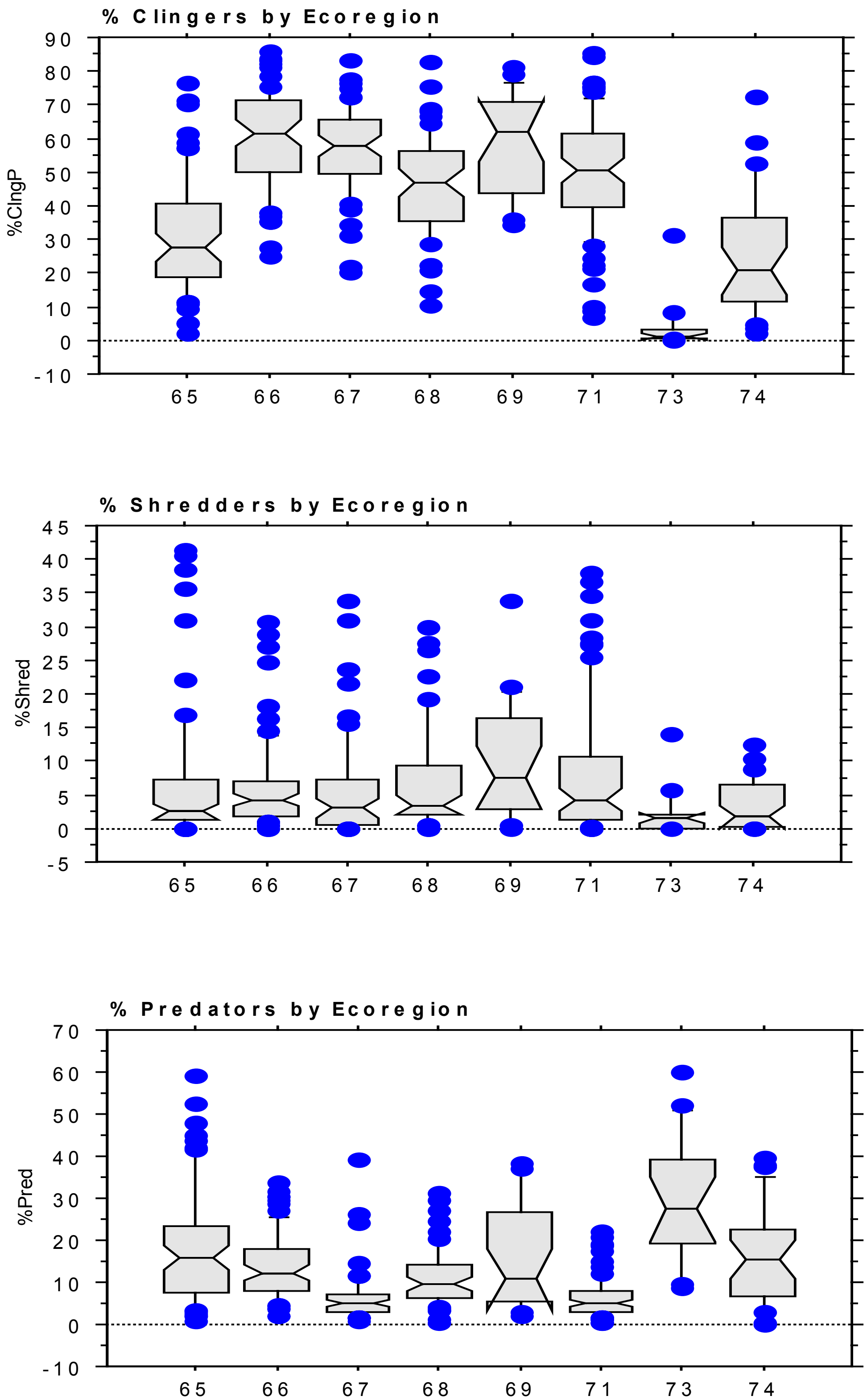


Figure 5: Range in habit and feeding metrics for reference sites by ecoregion. Multiple sampling events at reference sites are included.

Seven metrics were selected as being the most responsive to changes in the structure of the macroinvertebrate community. The seven metrics selected were then evaluated for sensitivity by comparison between reference sites and stressed sites in two subregions (Figures 6-7).

Test sites in 67f were impaired primarily by dairy operations. Test sites in 71i were randomly chosen and reflect a variety of impacts including urban development and agriculture. Test sites in 71i were further broken down by stream type; glide pool (bank sample) or riffle run (kick sample). This provided an indication of each metric's sensitivity between the two major stream types.

Six of the metrics were clearly responsive to disturbances in both regions. The percent oligochaete and chironomid metric proved less responsive. However, it was the most viable composition metric after the percent EPT that did not measure an overlapping component of the benthic community. Based on past assessments, the percent oligochaetes and chironomids has proven to be effective in water quality assessments throughout the state. The seven most responsive metrics were:

Richness Metrics:	EPT Richness (Ephemeroptera, Plecoptera, Trichoptera)
	Taxa Richness
Composition Metrics:	% OC (% Oligochaeta and Chironomidae)
	% EPT (% Ephemeroptera, Plecoptera, Trichoptera)
Tolerance Metric:	NCBI (North Carolina Biotic Index)
	% Dominant
Habit Metric:	% Clingers

1. **EPT Richness** measures the diversity of this group of taxa without regard to abundance. This taxa group, which included the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), is considered one of the most important in the macroinvertebrate community. Organisms in these orders are often the first to disappear in response to stressors including habitat alteration, toxicants, sedimentation and nutrient enrichment.

2. **Taxa Richness** measures the total number of individual taxa without regard to abundance. Generally, the number of different organisms decreases with increased pollution.

3. **% OC** measures the abundance of oligochaetes (aquatic worms) and chironomids (midge larvae). This metric usually increases in response to factors such as low dissolved oxygen levels and excessive sedimentation. The majority of the organisms in these two groups are considered tolerant or facultative. Although a few intolerant genera are included in this group, the % OC only becomes a dominant portion of the benthic community in stressed situations.

4. **%EPT** is a measure of the relative abundance of Ephemeroptera, Plecoptera, and Trichoptera. These three orders are generally reduced in numbers in stressed conditions.

5. The **NCBI** (North Carolina Biotic Index) is a measure of the overall tolerance level of the entire benthic community. A healthy macroinvertebrate population will include animals at all tolerance levels, however, the number of tolerant organisms should be comparatively low. The NCBI measures both the tolerance level of individual taxa and the overall abundance of those taxa. The NCBI is most sensitive to organic enrichment although it measures other stressors such as habitat alteration and sedimentation as well.

6. The **% Dominant** is the relative abundance of the single most common taxon in the sample. The dominance of a single taxon demonstrates an imbalance in the structure of the macroinvertebrate community. An organism usually becomes dominant when it is able to tolerate a stressor that limits the survival or reproduction of other taxa.

7. The percent Clingers **(% Clingers**) is generally a measure of physical aspects of the environment such as habitat disturbance, sedimentation, flow alteration and substrate stability. These animals build fixed retreats or have adaptations to attach to surfaces in flowing water. They are dependent on availability of stable, sediment-free substrates.

The water penny (Coleoptera, Psphenidae) is an example of a clinger organism that is dependent on sediment-free substrate. (Photo provided by Cliff White, Missouri Stream Team.)

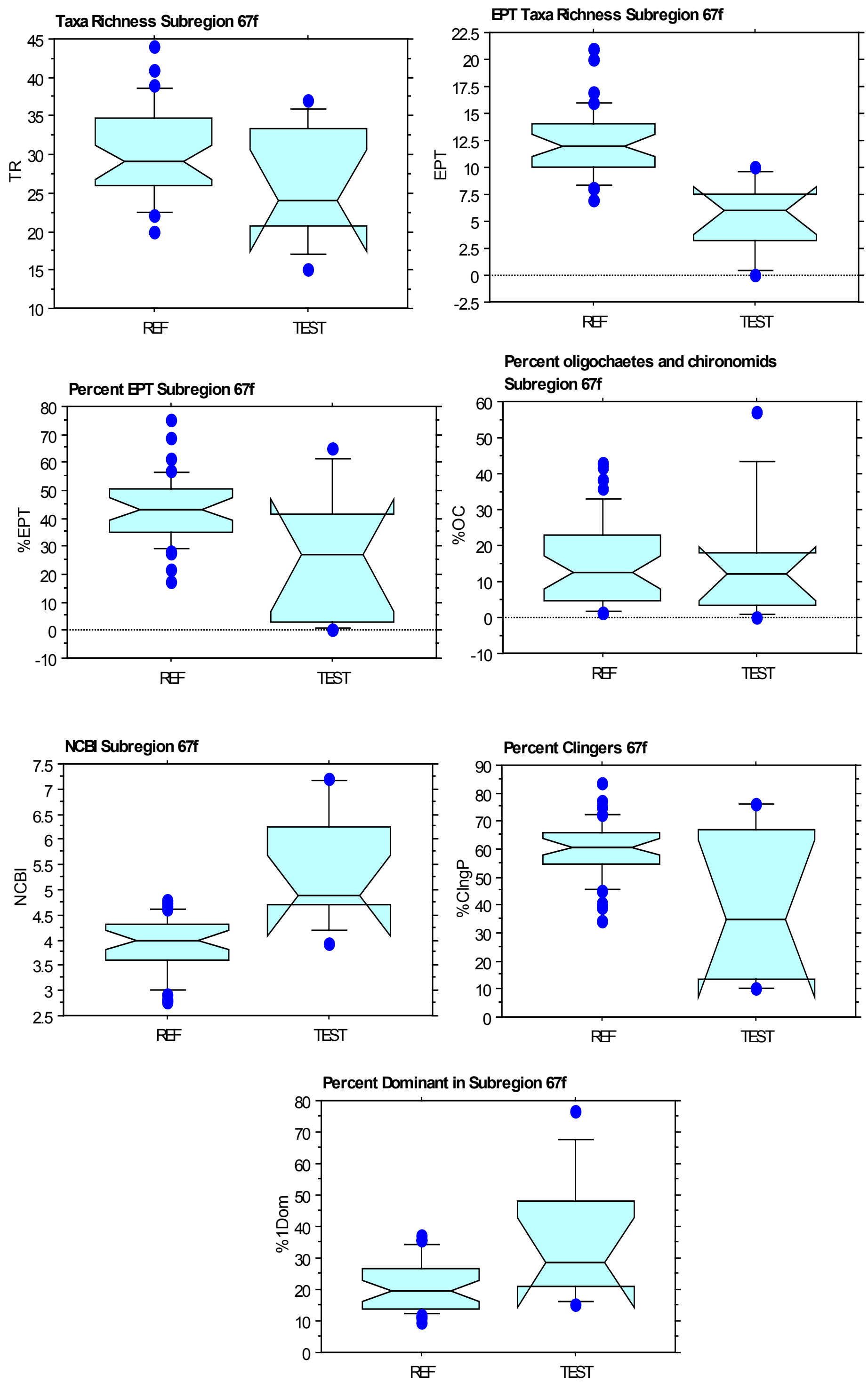


Figure 6: Comparison of potential biometrics between seven reference sites and nine impaired test sites in the Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f). Multiple sampling events at reference sites and a single sampling event at each test site are included. (Reference Sites: N = 27, Sites = 7; Test Sites: N = 9, Sites = 9)

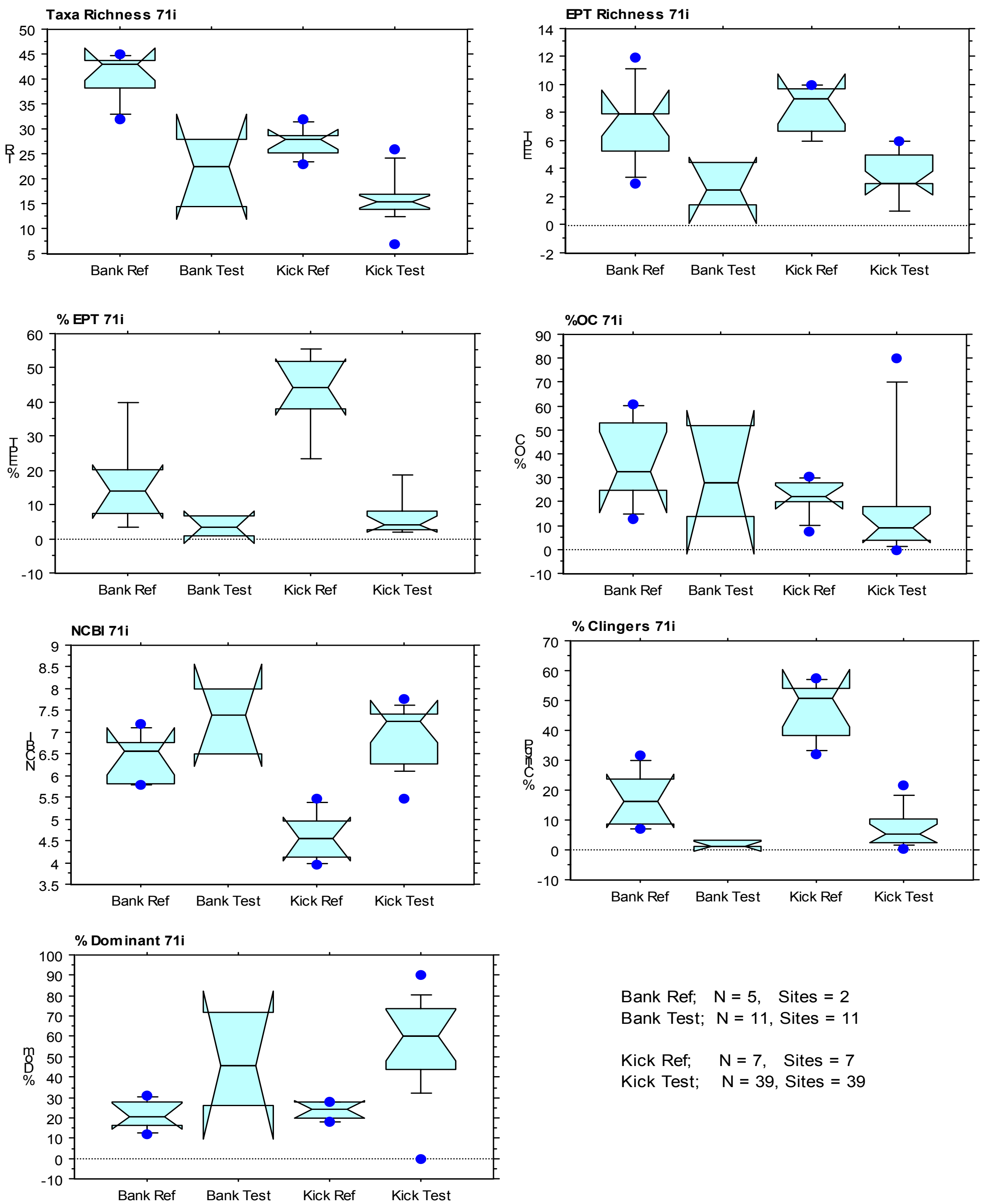


Figure 7: Comparison of potential biometrics between reference sites and test sites in the Inner Nashville Basin (71i). Data are separated by sample type (Kick or Bank). Reference sites are multiple samples at nine sites. Test sites are single samples at 50 randomly selected sites.

4. FINAL REFERENCE SITE REVIEW

The macroinvertebrate data from each of the 114 potential reference sites were compared to the other sites in the same subregion for the seven metrics selected. Box and Whisker plots were used to determine whether biological data at each site demonstrated overlap at the 25th or 75th percentile depending on the metric. Sites were not dropped based on metric comparison alone. Any site that appeared inconsistent with the others for three or more metrics was re-evaluated for acceptability as representing reference condition for that subregion. This was accomplished through review of field notes, habitat scores and correspondence with field biologists who had monitored the sites.

For example, in the Western Highland Rim (71f) 7 potential reference sites had been targeted for monitoring. However, data ranges in ECO71F01, Panther Creek appeared to be dissimilar to the other reference sites for taxa richness, NCBI and the percent dominant taxon (Figure 8). Discussion with field office personnel and review of field notes revealed this stream was subject to flash flooding with a very unstable gravel substrate. Subsequently, this site was dropped from the reference database.

On the other hand, comparison of five potential reference sites in the Cumberland Mountains (69d) show satisfactory overlap of the majority of metrics (Figure 9). Coal mines are common in this region. Only two of the reference streams (ECO69D01 and ECO69D03) had no significant historic mining impacts. The other three had some degree of impact based on elevated conductivity, metals and sulfate levels. However, a comparison of all five sites demonstrated no consistent variation in the benthic community. Therefore, all five sites were used in calculation of the proposed biological criterion. This also supports the argument that non-reference sites in this subregion should be able to maintain similar benthic communities.

After statistical and field evaluation, sixteen of the candidate reference sites were dropped from consideration. The majority of these sites had already been targeted by field biologists as being too impaired for reference use after intensive monitoring revealed impacts that were not readily observable during the initial field screening. This left 98 reference sites that were used for biocriteria development. A list of reference sites used for biocriteria determination can be found in appendix B. The sites that were intensively monitored but not used for criteria development are summarized in appendix C.

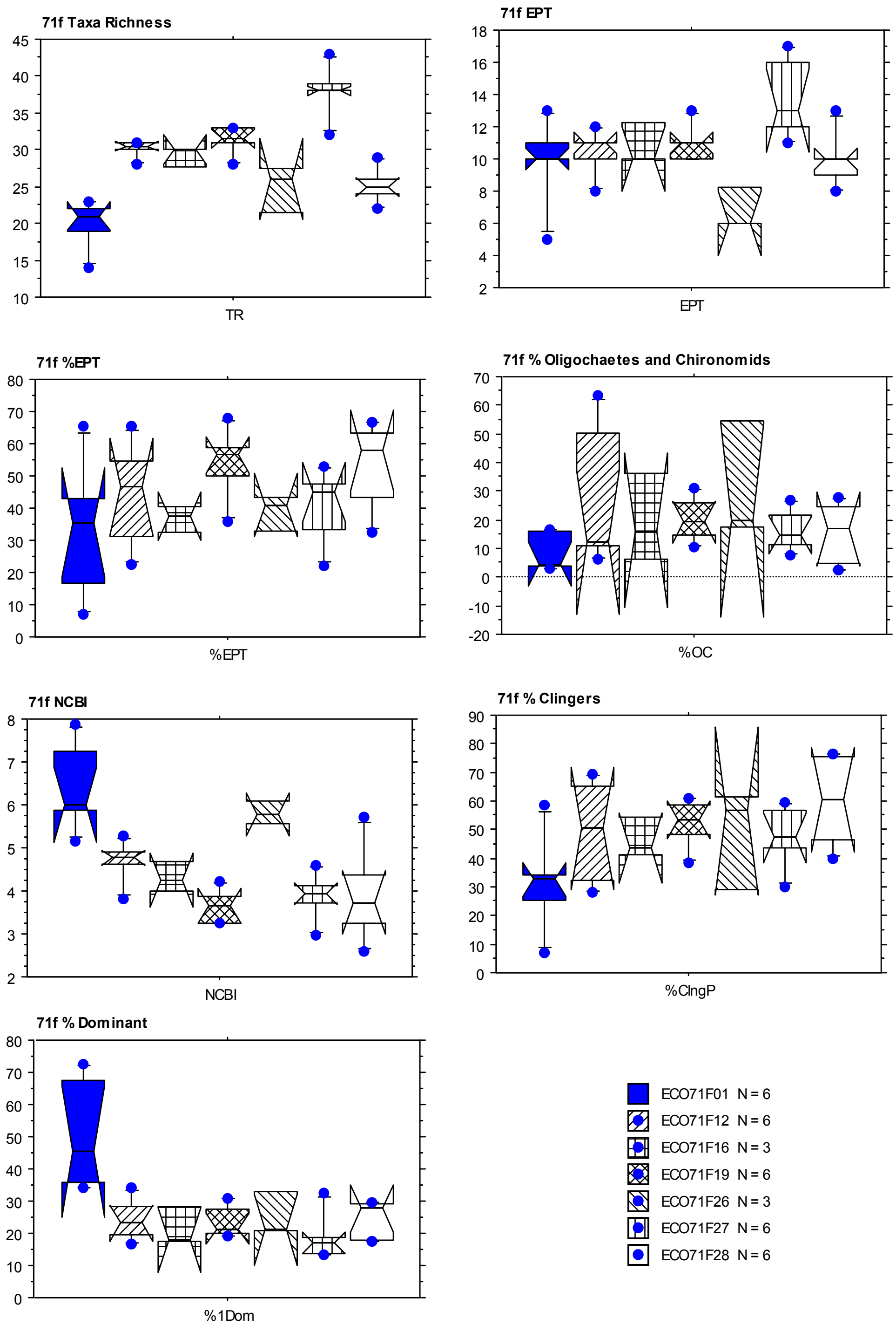


Figure 8: Comparison of seven biometrics at seven potential reference sites in the Western Highland Rim (71f). Data represent multiple samples over a 4-year period. Stations ECO71F01 and ECO71F26 were dropped from consideration as reference sites.

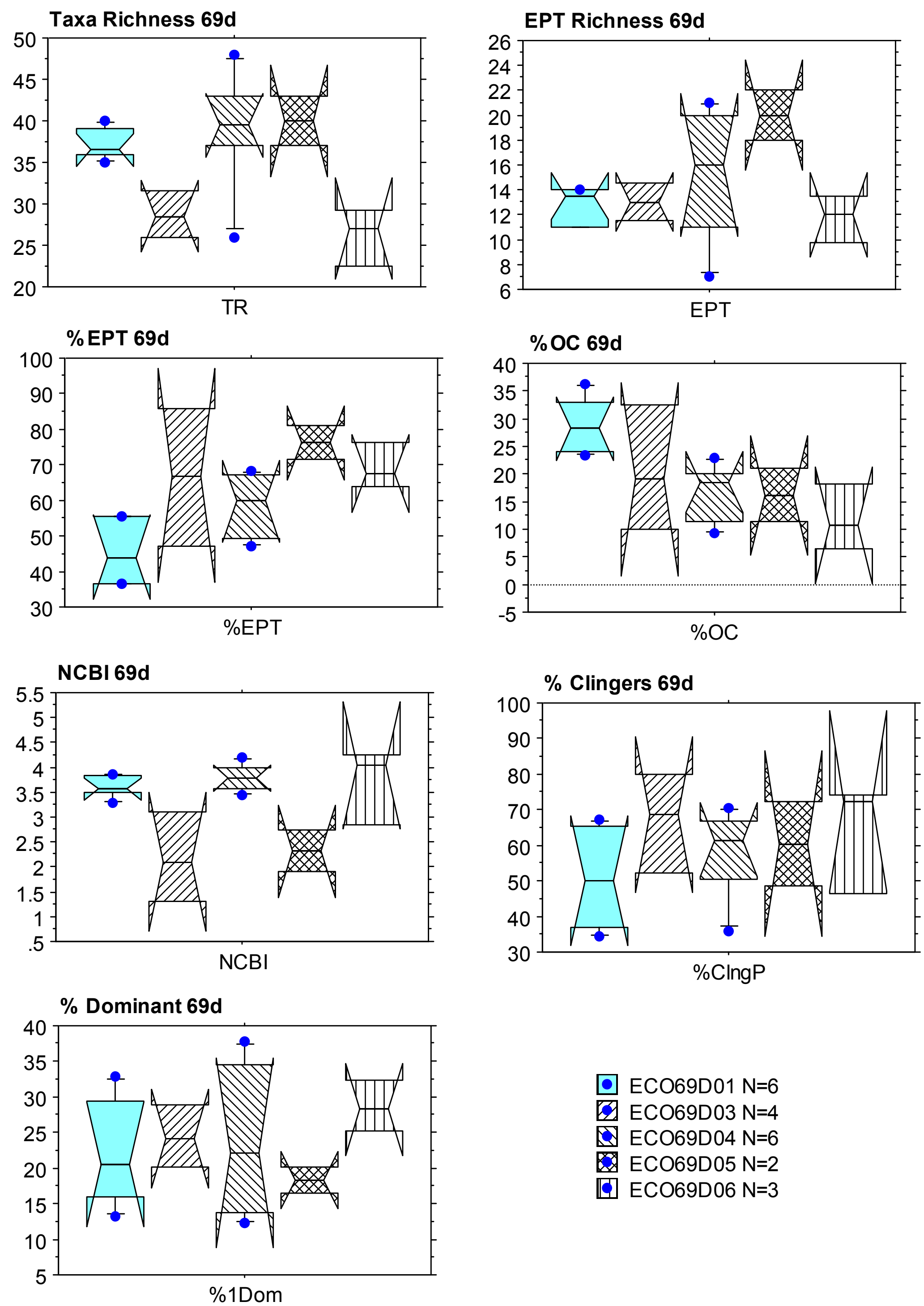


Figure 9: Comparison of biometrics at five reference sites in the Cumberland Mountains (69d). Data at each site represent multiple samples collected over a 5-year period.

5. ESTABLISHING BIOREGIONS AS A FRAMEWORK FOR BIOASSESSMENT

Reference data in each Level IV subregion were evaluated to determine if the subregion supported a distinct benthic community or could be grouped with other subregions into a bioregion. Adjacent Level III ecoregions that were sampled using the same gear type (rooted bank or riffle kick) were also compared.

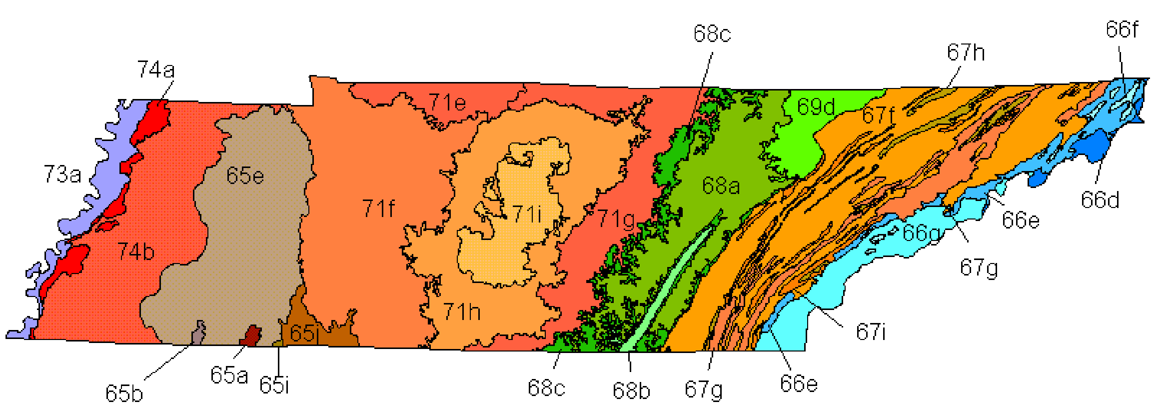
Evaluations for benthic community similarity were accomplished through multivariate ordination. The ordination method used was multi-dimensional scaling (Kovach, 1999). Multi-dimensional scaling (MDS) is a technique for finding a configuration of points in dimensional space that represents multivariate data. Unrelated values will map to distant points, while related values will become clustered. MDS and cluster analysis depend on a dissimilarity measure defined for all pairs of objects in the data set to be viewed. Similarity between site pairs was measured using Gower's Similarity Coefficient. Data were equalized prior to analysis so that all metrics were given equal weight.

Using this method, several level IV subregions, as well as two level III ecoregions proved to have similar benthic populations and were combined for criteria development. The result was 15 distinct bioregions with one bioregion (71i) being split based on stream type (Table 2). Each grouping contained streams of various size classes.

The Inner Nashville Basin (71i) is the only subregion where both riffle (kick sample) and non-riffle (rooted bank sample) biocriteria were developed. Both stream types are common in this region with streams sometimes changing characteristics by season. Photo provided by Aquatic Biology Section, TDH.

Table 2: Similarity groupings of Level III and Level IV ecoregions based on reference stream data collected between 1996 and 2001.

Grouped Subregions	Sample Method	No. of Sites	Stream Orders
65a, 65b, 65e, 65i, 74b	SQ BANK	65a-2 65b-1 65e-6 65i-1 74b-3	65a-2 65b-3 65e-2, 3, 3, 3, 3, 3 65i-2 74b-2, 2, 4
65j	SQ KICK	4	2, 3, 2, 2
66d, 66e, 66g		66d-5 66e-5 66g-5	66d-2, 4, 4, 1, 2 66e-2, 4, 3, 2, 2 66g-4, 4, 4, 2, 3
66f	SQ KICK	4	1,3,4,3
67, 67f, 67h, 67i	SQ KICK	67 (cross regions)-3 67f-7 67h-3 67i-1	67 (cross regions)-3, 2, 3 67f-3, 2, 3, 5, 3, 4, 2 67h-1, 2, 1 67i-3
67g	SQ KICK	4	4, 4, 3, 3
68a	SQ KICK	8	3, 3, 5, 2, 3, 4, 3, 5
68b	SQ KICK	3	2, 3, 2
68c	SQ KICK	4	1, 2, 1, 1
69d	SQ KICK	5	2, 2, 3, 2, 3
71e	SQ KICK	2	3, 3
71f,g, h	SQ KICK	71f-5 71g-3 71h-3	71f-3,3,4,2,4 71g-4,5,3 71h-4,3,4
71i	SQ KICK	7	3, 3, 3, 3, 3, 3, 4
71i	SQ BANK	2	3, 3
73a	SQ BANK	4	3, 4, 4, 4
74a	SQ KICK	2	2, 2



5.0 Comparison of Macroinvertebrate Communities in the Southeastern Plains (Ecoregion 65)

There are five subregions within the Southeastern Plains (ecoregion 65). Three of these subregions (65a, b, and i) cover a very small part (1.6%) of the ecoregion (Figure 10). Streams targeted as least impaired in these three subregions were of marginal reference quality although they were the best available due to the limited number of streams. These three regions cover such small areas in Tennessee they are probably not unique and are similar to 65e in composition as indicated in Figure 11. One of these small subregions, the Blackland Prairie (65a), demonstrated some distinct clustering. However, this was based on only six data points. Therefore, these subregions were grouped with subregion 65e (Southeastern Plains and Hills), which comprises 90% of the region. Mississippi and Alabama have larger regions of 65a, b and i. When available, reference data from these states will be compared to Tennessee's data to verify similarity between regions.

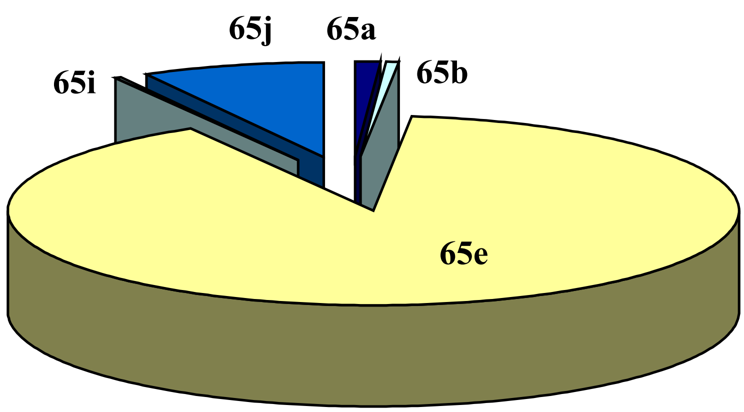


Figure 10: Percent contribution of level IV subregions in the Southeastern Plains (65)

Data from the Transition Hills subregion (65j) did not group with the other subregions (Figure 11). This region supports a distinct macroinvertebrate community with a greater number of intolerant organisms. This is probably a function of stream type. Streams in the Transition Hills generally have a higher gradient and different substrate (cobble) than the rest of the ecoregion. Riffles were prevalent in these streams and warranted an alternate collection method (riffle kick) than the rest of the ecoregion (rooted bank sweep).

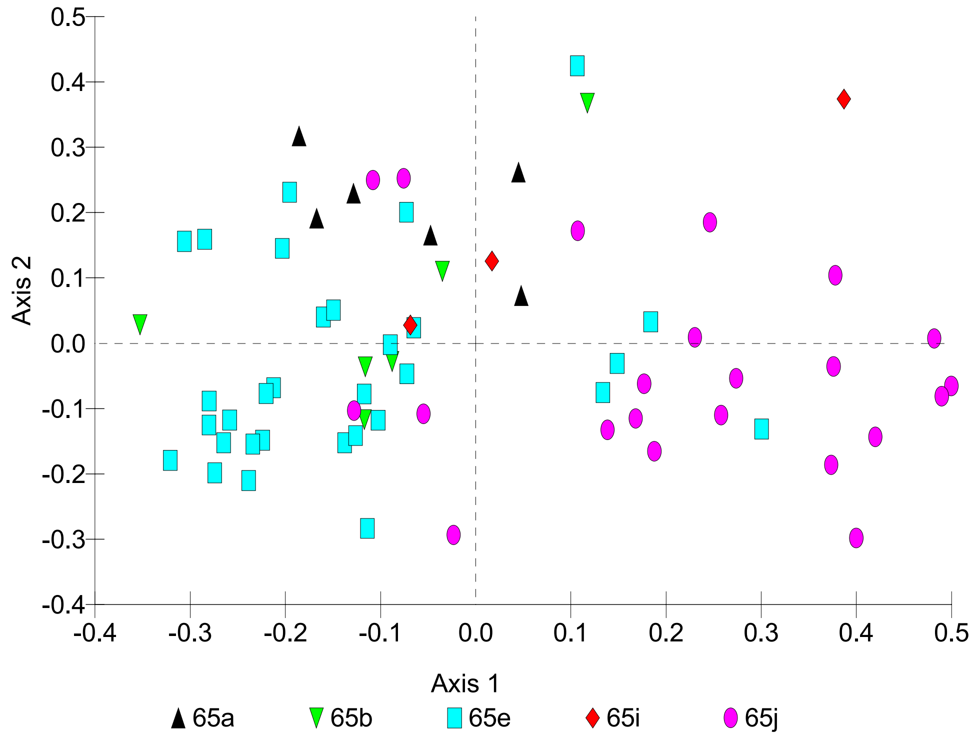


Figure 11: MDS ordination of reference data in five subregions within the Southeastern Plains (65). Plot is based on multivariate analysis of seven biometric scores for each sample. Data represent multiple samples at two sites in 65a, one site in 65b, six sites in 65e, one site in 65i and four sites in 65j.

Right Fork Whites Creek, Reference Stream in the Transition Hills (65j). Streams in this region are atypical of the glide/pool streams found in the rest of the Southeastern Plains ecoregion. Photo provided by Amy Fritz, JEAC, TDEC.

5.1 Comparison of Macroinvertebrate Communities in the Blue Ridge Mountains (Ecoregion 66)

There are four subregions located within the Blue Ridge Mountains ecoregion. The entire ecoregion only covers 6% of the state. The smallest level IV subregion in the Blue Ridge is 66f (Limestone Valleys and Coves) that comprises only 5.5% of the ecoregion. This was the only subregion that had a significantly different macroinvertebrate community from the rest of the ecoregion (Figure 12). Streams in the Limestone Valleys and Coves subregion (66f) are generally lower gradient than those in the other three subregions that represent ridges and mountains. A separate biocriterion was determined for this region while the other three were grouped.

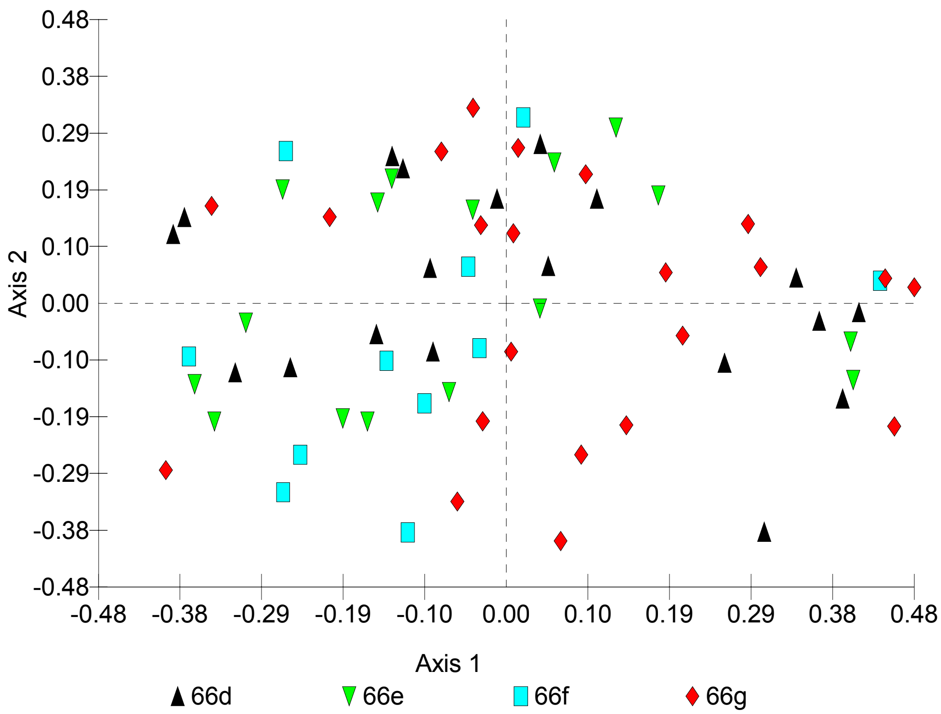


Figure 12: MDS ordination of reference data in four subregions within the Blue Ridge Mountains (66). Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at five sites each in 66d, 66e and 66g, and four sites in 66f.

The Copper Basin area was included in subregion 66g, the Southern Metasedimentary Mountains (Griffith et al. 1997). Subsequent ecoregion delineation work conducted by Omernik and Griffith in North Carolina indicates that this area may be separated into a distinct subregion called the Broad Basins (66j). The new subregion would include several disjunct large basin areas of the Blue Ridge, including the Copper/McCaysville, Asheville, Waynesville/Canton, and Little TN/Franklin areas. Caution should be used in comparing streams in the Copper Basin to 66g criterion until reference data in the Copper Basin area can be collected and compared for similarity to 66g reference data.

5.2 Comparison of Macroinvertebrate Communities in the Ridge and Valley (Ecoregion 67)

This is a large ecoregion encompassing 18.2% of the state. There are four level IV subregions within the Ridge and Valley ecoregion. The majority of the region (69%) falls within the Southern Limestone/Dolomite Valleys and Low Rolling Hills subregion (67f). Figure 13 illustrates how streams in this subregion supported a benthic community similar to the Southern Sandstone Ridges (67h) and the Southern Dissected Ridges and Knobs (67i).

Three reference stations were located on streams that crossed subregional boundaries. These stations are designated by the label 67 in Figure 13. All three of these streams included some drainage within subregion 67f. Two also had drainage in 67h (Southern Sandstone Ridges) while the third had drainage in 67g (Southern Shale Valleys). The specific sampling reaches were all located in region 67f. Multivariate analysis indicated the macroinvertebrate populations in all three stations that crossed subregions were statistically similar to subregion 67f. Therefore, data from these three sites were combined with data from subregions 67f, h and i for criteria determination.

Streams entirely within the Southern Shale Valleys subregion (67g) proved to have a distinct benthic structure (Figure 13). The macroinvertebrate community in this region had a more facultative population with fewer EPT than the other subregions.

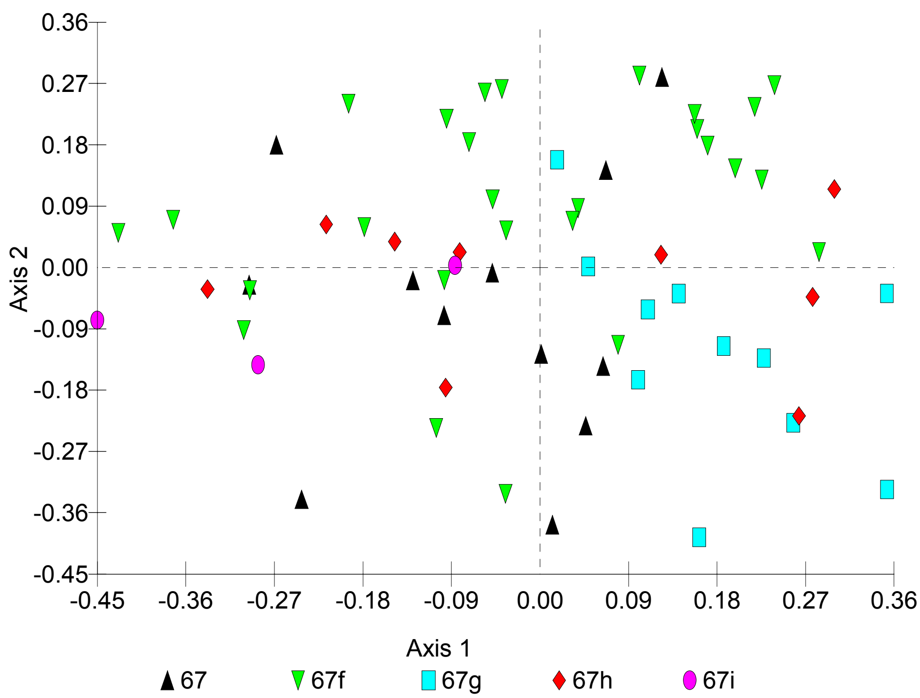


Figure 13: MDS ordination of reference data in four subregions within the Ridge and Valley (67). Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at seven sites in 67f, four sites in 67g, three sites in 67h and one site in 67i. Three sites that crossed subregions are represented by category 67.

5.3 Comparison of Macroinvertebrate Communities in the Southwestern Appalachians (Ecoregion 68)

There are three subregions in the Southwestern Appalachians ecoregion. The largest is the Cumberland Plateau, which covers 66.2% of the ecoregion. Figure 14 illustrates the similarity groupings between these three regions. The benthic community in the Cumberland Plateau (68a) was distinctly different from the Plateau Escarpment (68c). Sequatchie Valley streams (68b) demonstrated similarity to both of the other regions, however, could not be clearly grouped with either one. The benthos reflect stream gradient and habitat, which are very different between the three subregions. Escarpment streams generally originate on the Cumberland Plateau. However, the steeper gradient supports a different benthic population. Likewise, Sequatchie Valley streams receive much of their flow off the escarpment, but the habitat and flow regimes of the valley are very different. The predominant land use in the Sequatchie Valley is agriculture, which also influences the reference condition.

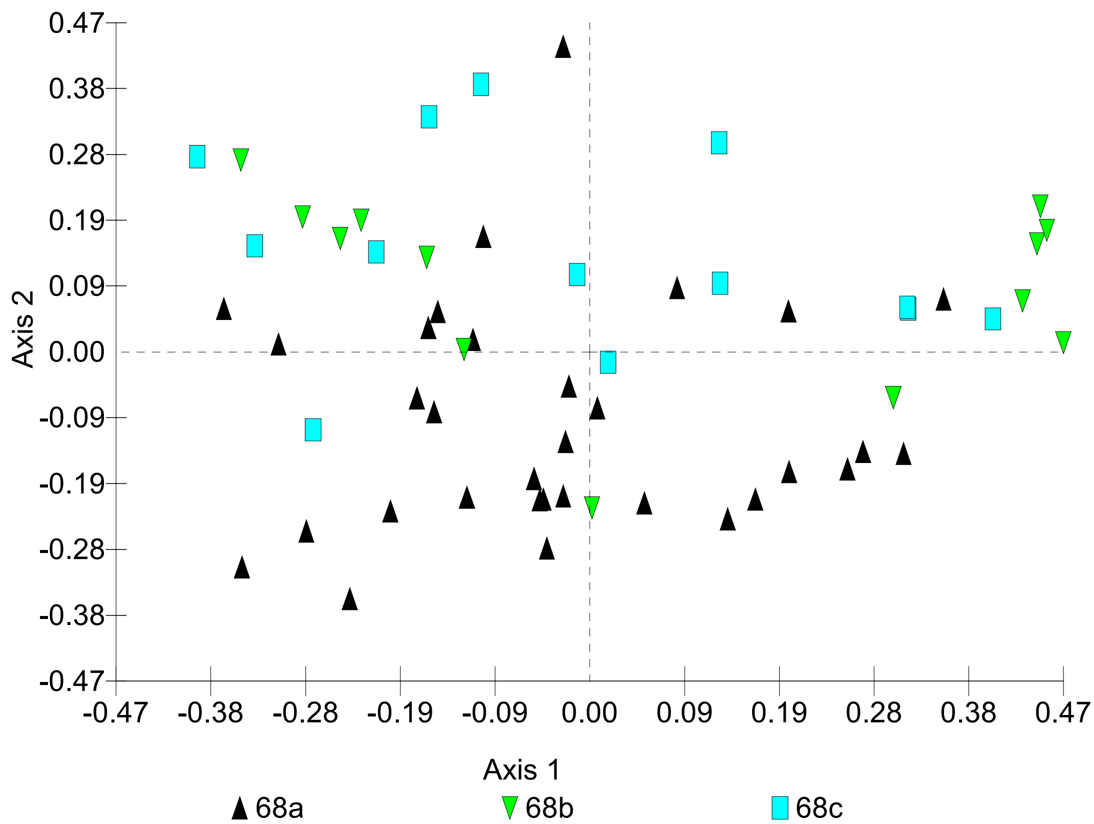


Figure 14: MDS ordination of reference data in three subregions within the Southwestern Appalachians (68). Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at eight sites in 68a, three sites in 68b and four sites in 68c.

5.4 Comparison of Macroinvertebrate Communities in the Central Appalachians (Ecoregion 69)

There is only one subregion, 69d, the Cumberland Mountains, located within the Central Appalachians ecoregion in Tennessee. This is a relatively small ecoregion, covering only 2.1% of the state. The region was well represented with five reference streams monitored.

Coal mines are common in this region. Only two of the reference streams (ECO69D01 and ECO69D03) had no significant historic mining impacts. The other three had some degree of impact based on elevated conductivity, metals and sulfate levels. However, a comparison of all five sites demonstrated no consistent variation in the benthic community. Therefore, all five sites were used in calculation of the proposed biological criterion. This also supports the argument that non-reference sites in this subregion should be able to maintain similar benthic communities.

ECO69D04 Stinking Creek reference site in the Cumberland Mountains. Elevated conductivity, metals and sulfate levels indicate residual influence from historic mining activities. However, the benthos were reference quality based on comparison to the two reference streams with no mining influences in this subregion. Photo provided by TDH.

5.5 Comparison of Macroinvertebrate Communities in the Interior Plateau (Ecoregion 71)

The Interior Plateau (71) is the largest ecoregion in Tennessee, covering 37.4% of the state. Ecoregion 71 is composed of five subregions. The Western Highland Rim (71f) and the Outer Nashville Basin (71h) are the largest subregions (Figure 15).

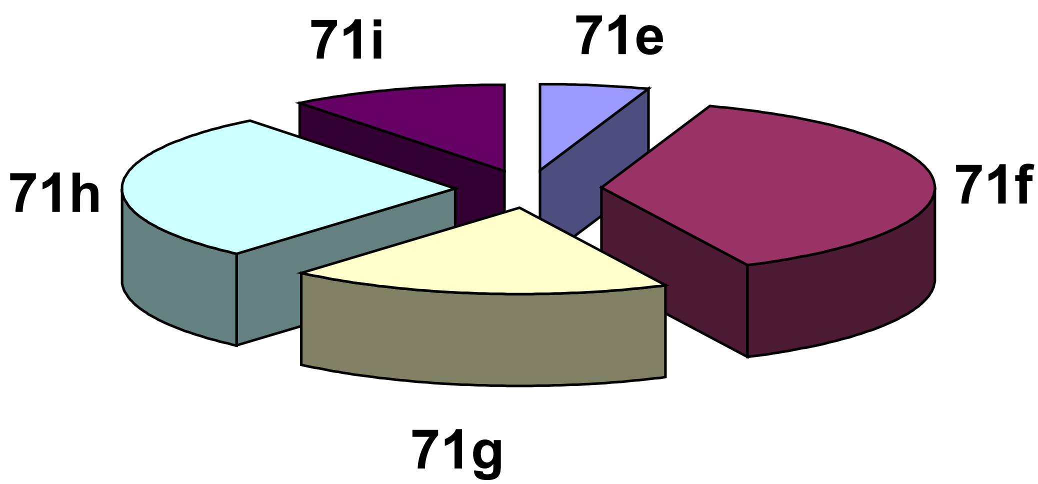


Figure 15: Percent contribution of subregions within the Interior Plateau (71)

Three subregions; the Outer Nashville Basin (71h), the Western Highland Rim (71f) and the Eastern Highland Rim (71g) had similar macroinvertebrate communities and were grouped for development of biocriterion (Figure 16). The Western Pennyroyal Karst (71e) and the Inner Nashville Basin (71i) had distinct benthic populations.

Two stream types are common in the Inner Nashville Basin (71i). In a probabilistic monitoring study where 50 streams were randomly selected in this subregion, 22% were glide pool and 78% had riffle habitat. Either riffle kicks or rooted banks were collected at the reference streams dependent on stream type. This is the only subregion where two sample types were necessary. The two methods generated distinct benthic communities (Figure 16). Therefore, different index ranges were calculated for 71i depending on sample type.

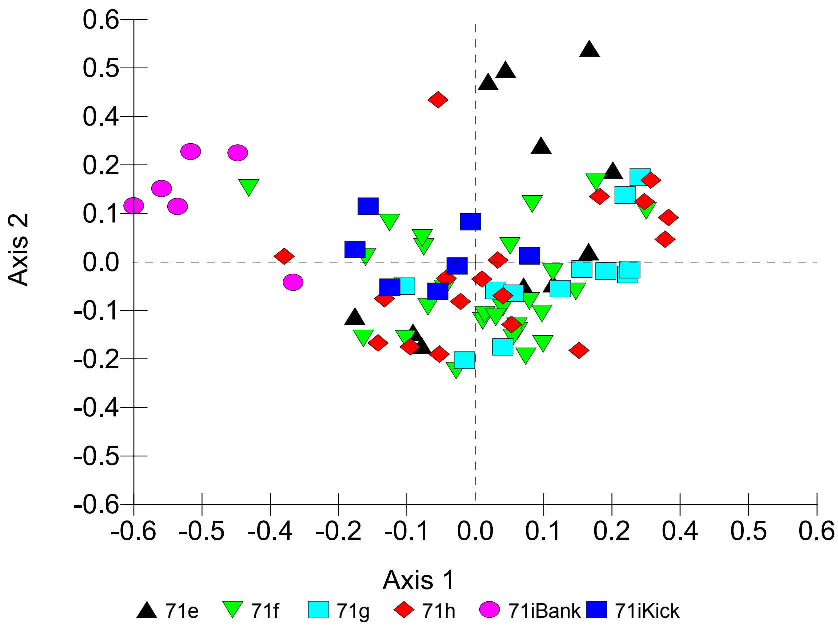


Figure 16: MDS ordination of reference data in five subregions within the Interior Plateau (71). Data are split by sample type (kick or bank). Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at two sites in 71e, five sites in 71f, three sites in 71g, three sites in 71h, seven sites in 71i kick, and two sites in 71i bank.

Flat Creek, a reference site in the Eastern Highland Rim (71g). Streams in this region were biologically similar to streams in the Western Highland Rim (71f) and the Outer Nashville Basin (71h). Data from all three subregions were combined into one bioregion for development of biocriteria. Photo provided by Jimmy Smith, NEAC, TDEC.

5.6 Comparison of Macroinvertebrate Communities in the Mississippi Alluvial Plain (Ecoregion 73)

In Tennessee, ecoregion 73 contains a single subregion, the Northern Mississippi Alluvial Plain (73a). The region is small, comprising only 2% of the state. This is primarily an agricultural area with a significant number of streams impaired from channelization, loss of riparian vegetation, sedimentation, erosion, pesticides and fertilizers. Reference stream selection was limited to those streams having the most stable habitat or widest riparian zone since all were impaired to some extent. Conversations with biologists in Mississippi and Kentucky indicated that streams in this region appear to be universally impaired. When available, data will be compared to sites in adjacent states to determine whether these sites are comparable to what is best attainable in the ecoregion.

According to Glen Griffith, USDA-NRCS, the entire Mississippi Alluvial Plains ecoregion is currently being sub-delineated. A second subregion, the Pleistocene Valley Trains (73d) is being proposed in the Dyer County area of Tennessee. If the splitting of this ecoregion is finalized, streams in the new subregion (73d) will be targeted to see if they are comparable to established reference streams in the Mississippi Alluvial Plain ecoregion. In addition, the sub-delineation may result in the name of 73a being changed from the Northern Mississippi Alluvial Plain to the Mississippi River Meander Belts.

Streams in the Northern Mississippi Alluvial Plain (73a) are low gradient with a shifting sand substrate. Channelization and bank erosion are common providing little stable habitat for macroinvertebrates. Photo provided by Aquatic Biology Section, TDH.

5.7 Comparison of Macroinvertebrate Communities in the Mississippi Valley Loess Plains (Ecoregion 74)

The Mississippi Valley Loess Plains ecoregion is comprised of two distinct subregions. The largest subregion 74b (Loess Plains) encompasses 89% of the region. The streams in 74b are typically glide/pool although gravel/small cobble riffle areas occasionally occur. Macroinvertebrate samples in this subregion were collected from the rooted undercut bank, as it was the only habitat commonly available at all reference streams.

The other subregion within the Mississippi Valley Loess Plains, the Bluff Hills (74a), has a distinctly different topography with higher gradient riffle/run prevalent streams. Riffle kicks were collected to determine appropriate criterion in this region. The macroinvertebrate community proved to be distinct in this region when compared to 74b (Figure 17).

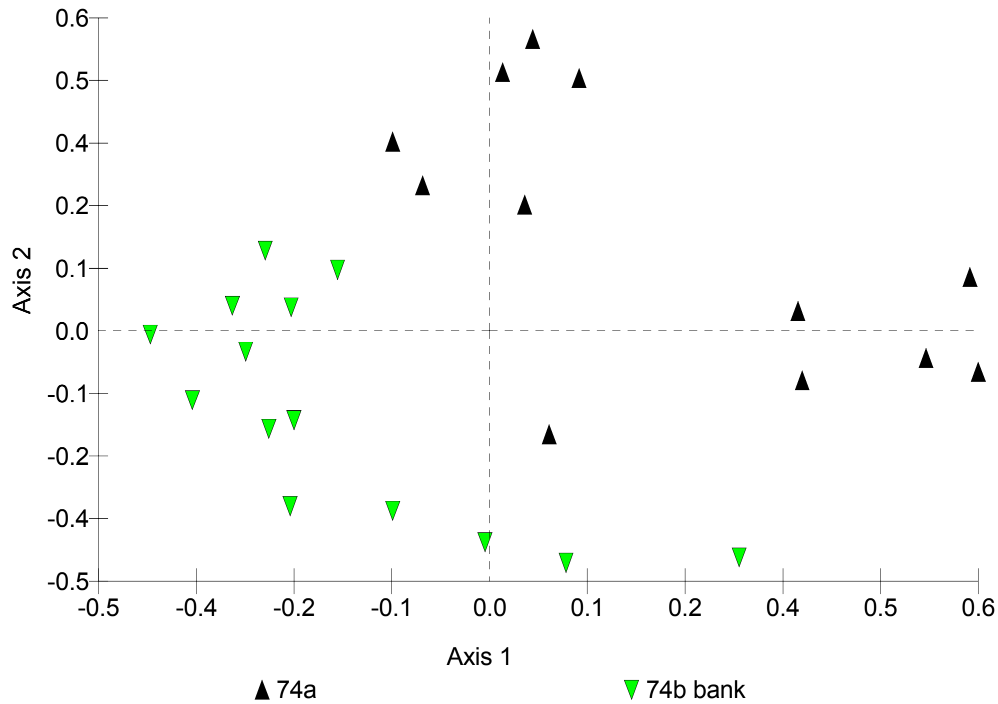


Figure 17: MDS ordination of reference data in two subregions within the Mississippi Alluvial Plains (74). Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at two sites in 74a and three sites in 74b.

5.8 Comparison of Macroinvertebrate Communities between Level III Ecoregions.

Once appropriate subregions were grouped, they were tested for similarity to subregion groups in adjacent Level III ecoregions to finalize development of bioregions. (For this study, a bioregion is defined as an ecological subregion or group of subregions that has a distinct macroinvertebrate community for assessment purposes.)

5.8.0 Comparison Between the Southeastern Plains, Mississippi Alluvial Plain and Mississippi Valley Loess Plains.

Subregion groups composed of non-riffle (glide-pool) streams in three ecoregions in west Tennessee were tested for similarity. This included the subregions 73a, 74b and the grouped subregion 65abei (Figure 18). Subregion 74b (Loess Plains) and the grouped subregion in the Southeastern Plains (65abei) exhibited similarity in the benthic community structure and were combined into a bioregion for biocriteria development. Most rivers and many of their tributaries cross these two subregions before entering the Mississippi River. By aggregating the data, streams that cross these regions can be assessed by comparison to the proposed criterion.

The Northern Mississippi Alluvial Plain (73a) appeared to have a distinct benthic structure when compared to the other west Tennessee ecoregions. Therefore, a separate biocriterion was proposed for this region.

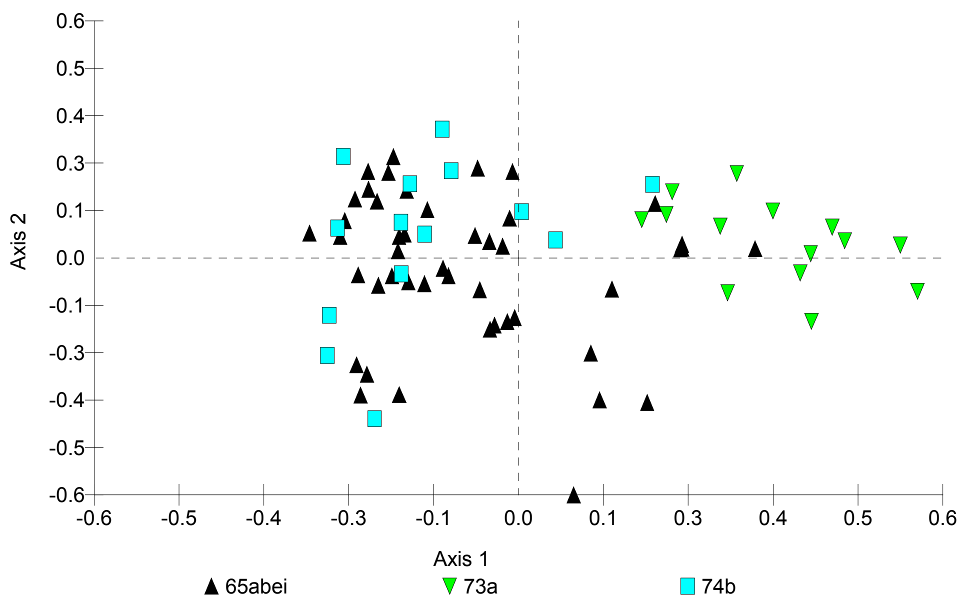


Figure 18: MDS ordination of reference data at selected subregion groups within three Level III ecoregions (65, 73, 74) in west Tennessee. Group 65abei includes four subregions. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at 10 sites in 65abei, 4 sites in 73a and 3 sites in 74b.

5.8.1 Comparison Between the Transition Hills, Cumberland Plateau, Plateau Escarpment and Interior Plateau

Subregion 65j (Transition Hills) was compared to the grouped subregion 71fgh in the Interior Plateau, the Cumberland Plateau (68a), and the Plateau Escarpment (68c). Based on MDS ordination, there was no clear clustering of data between these regions. Although some samples were similar, the largest concentration of coordinates for each region was in a separate area. The results of this comparison are presented in Figure 19.

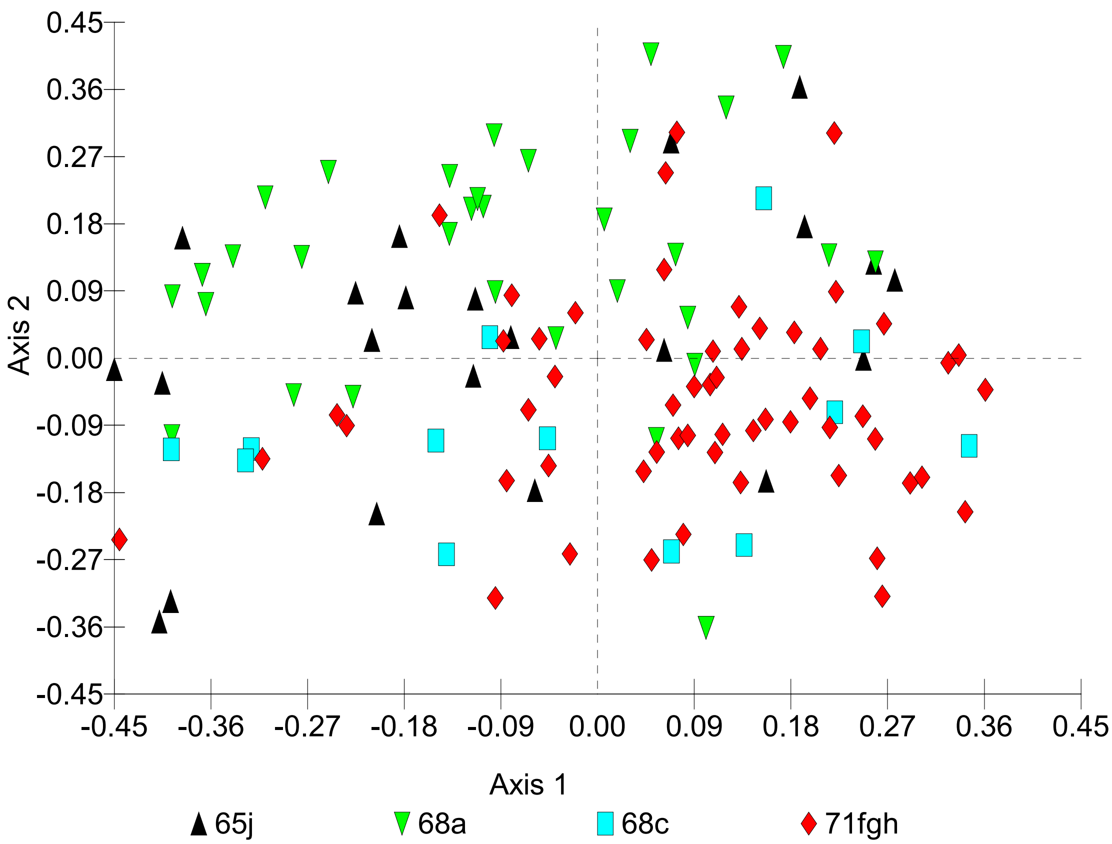


Figure 19: MDS ordination of reference data at selected subregion groups within three Level III ecoregions (65, 71, 68) in west, middle and east Tennessee. Group 71fgh includes three subregions. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at four sites in 65j, eight sites in 68a, 4 sites in 68c and 11 sites in 71fgh.

5.8.2 Comparison Between the Cumberland Plateau, the Cumberland Mountains and a Subregion Group in the Ridge and Valley.

The next regions to be compared for similarity of macroinvertebrate communities were the Cumberland Plateau (68a), the Cumberland Mountains (69d) and a grouped subregion in the Ridge and Valley ecoregion (67fhi). Figure 20 illustrates the ordination of this data. Once again, the greatest concentration of data in each group was not similar.

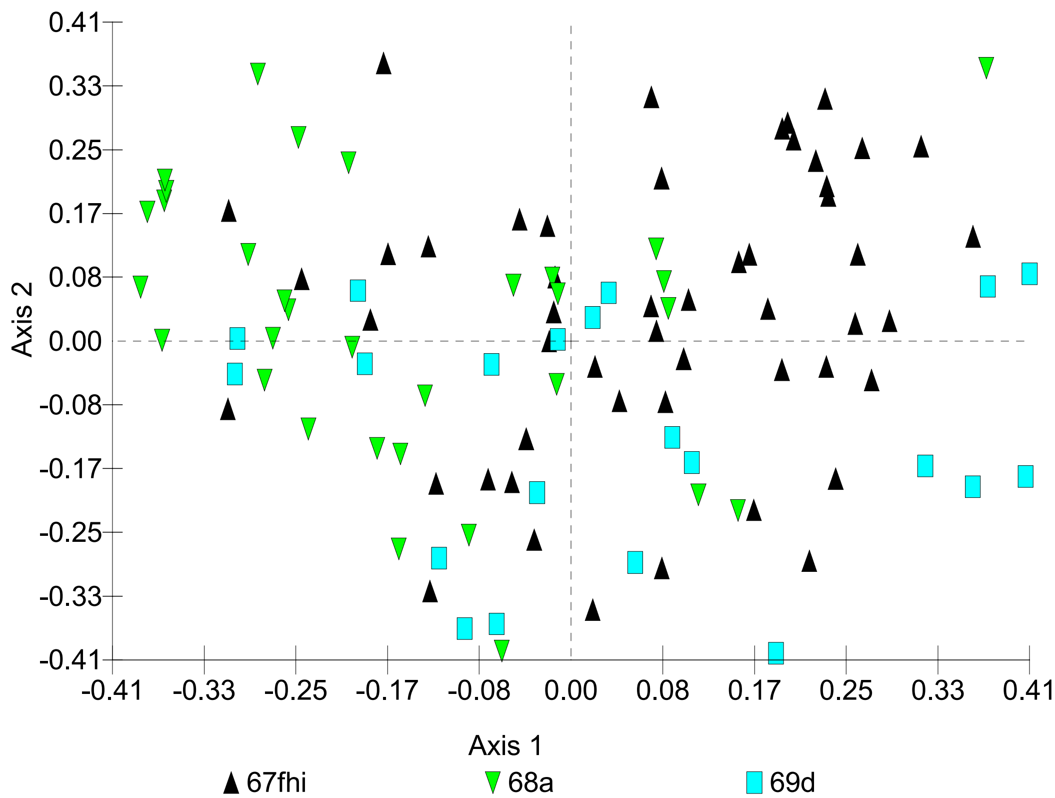


Figure 20: MDS ordination of reference data at selected subregion groups within three Level III ecoregions (67, 68, 69) in east Tennessee. Group 67fhi includes three subregions. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at 14 sites in 67fhi, eight sites in 68a, and 5 sites in 69d.

5.8.3 Comparison Between the Ridge and Valley and the Blue Ridge Mountains

The final Level III ecoregions to be compared were the grouped subregions in the Ridge and Valley (67) and the Blue Ridge Mountains (66). There was very little similarity between sites in these regions (Figure 21).

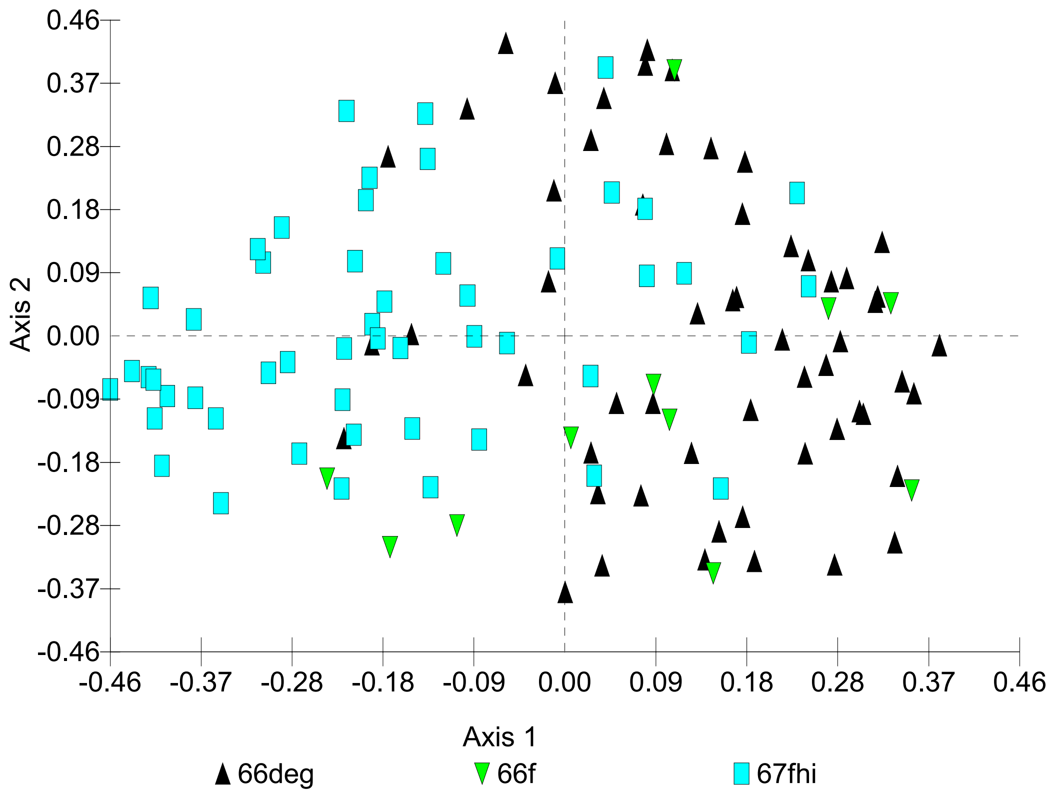


Figure 21: MDS ordination of reference data at selected subregion groups within two Level III ecoregions (66 and 67) in east Tennessee. Group 67fhi includes three subregions. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at 15 sites in 66deg, 4 sites in 66f and 14 sites in 67fhi.

6. EVALUATING SEASONAL VARIABILITY FOR INTERPRETING BIOLOGICAL RESPONSES.

After all subregions and ecoregions had been evaluated for community similarity, 15 bioregions demonstrating unique macroinvertebrate communities had been defined for development of biocriteria. These bioregions were evaluated for seasonal variations using multivariate analysis and ordinal plots. The ordination method was non-metric multidimensional scaling (MDS). Distances between site pairs were determined using Gower's Similarity Coefficient.

Where seasonal differences were apparent, all data were aggregated for metric range determinations. Biocriteria were then based on reference condition index scores for each season. For example, similarity to reference condition may be measured as a target index score of 32 in the spring and a score of 28 in the fall for a particular bioregion.

Seasonal variability was evident in the Cumberland Mountains (69d) where many streams have reduced flow in the late summer/fall season. Separate biocriteria dependent on season were developed in this region. Photo provided by Aquatic Biology Section, TDEC.

6.0 Seasonal Variability in Bioregion 65abei-74b.

Seasonal variation was not apparent in the bioregion that includes subregions 65a,b,e,i and 74b (Figure 22). However, samples in these regions were not collected within close enough time periods to ensure that seasonal differences would be identified. Due to the uncertainty of seasonal difference, a single year-round criterion was calculated.

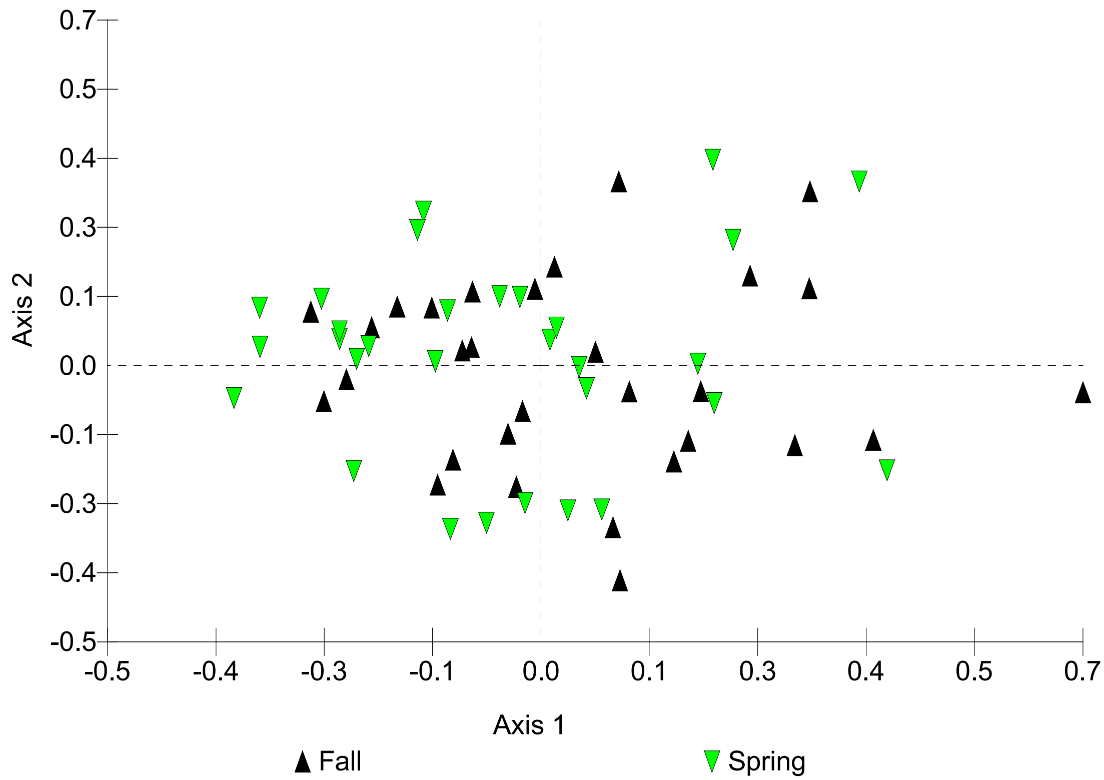


Figure 22: MDS ordination of spring and fall reference data in the bioregion that includes subregions 65a, 65b, 65e, 65i, and 74b. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples from 13 sites.

6.1 Seasonal Variability in Bioregion 65j.

Samples in the Transition Hills subregion (65j) were collected in tight seasonal windows. Data did not demonstrate clear seasonal differences (Figure 23). Therefore, a single scoring criterion, applicable year round, was calculated for this region.

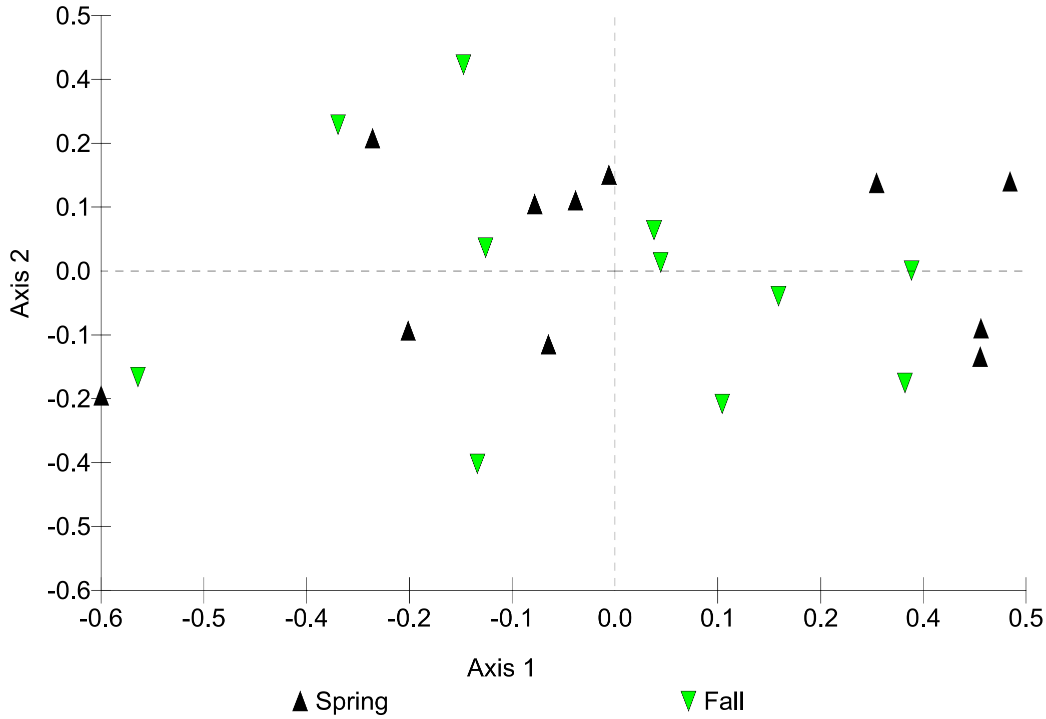


Figure 23: MDS ordination of spring and fall reference data in bioregion 65j. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples from four sites.

6.2 Seasonal Variability in Bioregion 66deg

Seasonal differences were not evident in the bioregion that included ecological subregions 66d, e and g (Figure 24). The data may be misleading, since these regions were not collected within the recommended 6-week seasonal windows. The spring window was 77 days and the fall window was 78 days. Because of the extended sampling periods and the fact that the data did not indicate seasonal variation, a single criterion applicable year round was proposed.

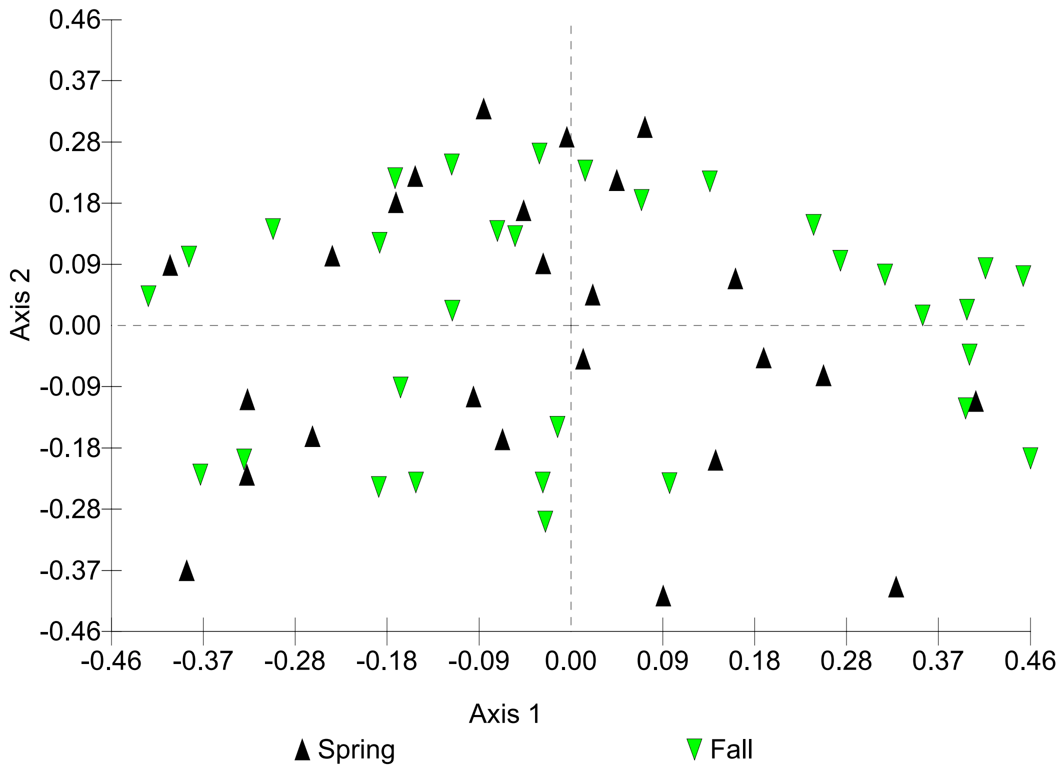


Figure 24: MDS ordination of spring and fall reference data in the bioregion that includes subregions 66d, 66e and 66g. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at 15 sites.

6.3 Seasonal Variability in Bioregion 66f.

Although samples were not collected within 6-week windows, a seasonal difference was observed in the benthic community of bioregion 66f (Figure 25). However, it should be noted that although four reference sites are represented, samples were only collected twice in the fall and once in the spring. Three metrics (taxa richness, EPT richness and % dominant) were more indicative of a diverse benthic community in the late summer/fall season while four metrics (%EPT, %OC, NCBI and % clingers) demonstrated a more diverse and pollution intolerant community in the spring (Figure 26). Combined index scores for reference sites in the late summer/fall season were higher than in the spring. Therefore, overall expectations in this region would be greater in the summer/fall than in the spring.

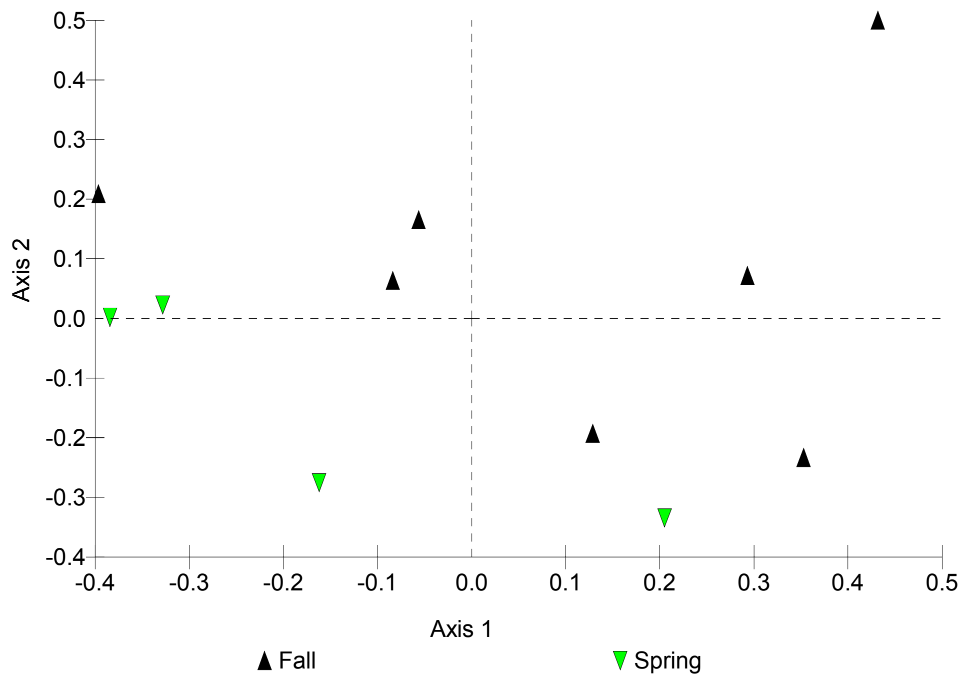


Figure 25: MDS ordination of spring and fall reference data in bioregion 66f. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at four sites.

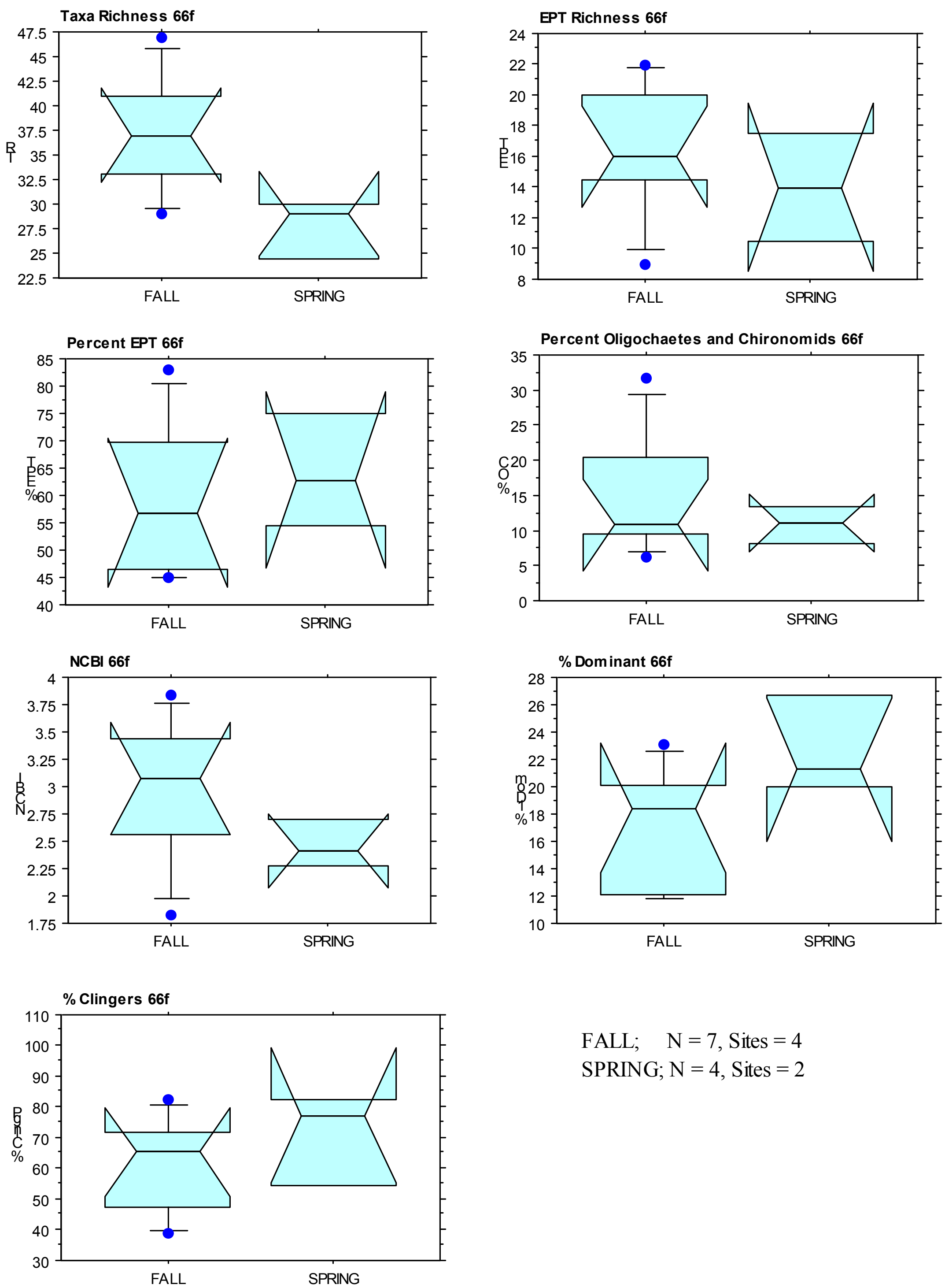


Figure 26: Distribution of reference data for individual biometrics by season in subregion 66f. Data represent multiple samples from four sites in the fall and two sites in the spring.

6.4 Seasonal Variability in Bioregion 67fhi

Benthic samples in the bioregion that included subregions 67f, h, and i did not demonstrate seasonal variation (Figure 27). Whether this was because of the extended sampling periods or a reflection of the benthic composition is uncertain. The proposed criterion, based on collected reference data, will be applicable year round. This could be adjusted if future sampling in tighter windows indicates significant seasonal changes in the macroinvertebrate community structure of streams in this region.

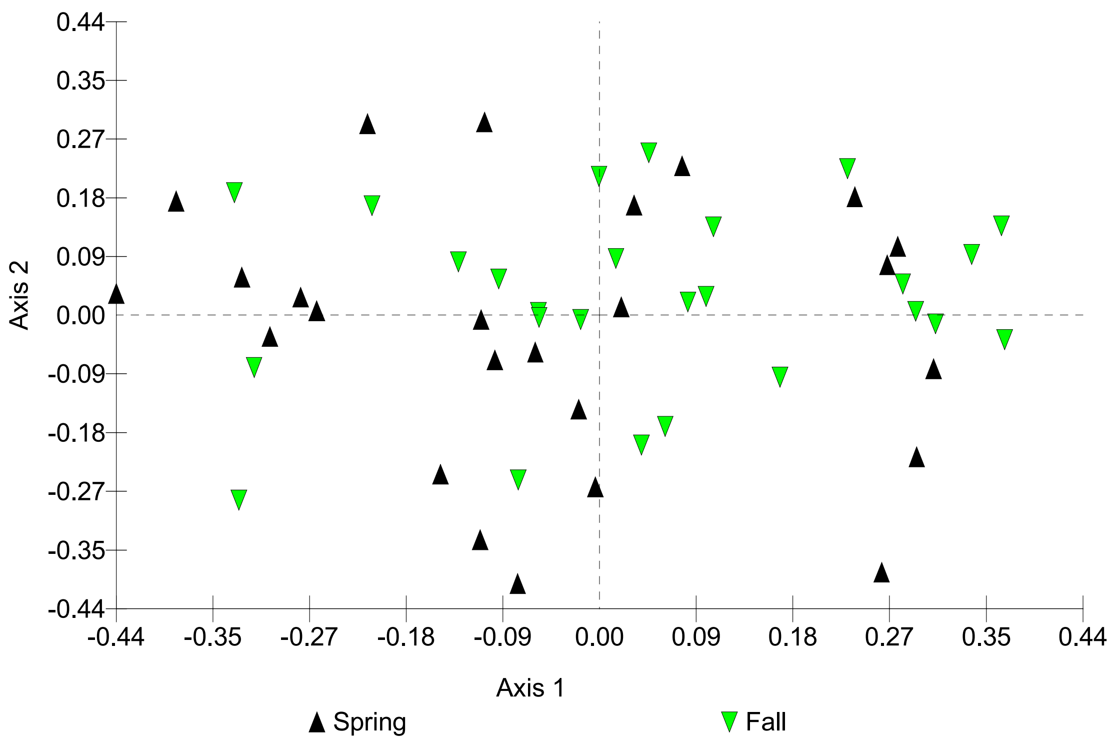


Figure 27: MDS ordination of spring and fall reference data in the bioregion that includes subregions 67f, 67h and 67i. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at 14 sites.

6.5 Seasonal Variation in Bioregion 67g

Spring samples in 67g were collected within a 10-day window over the three-year sampling period. However there was a 102-day spread on the summer/fall collection with samples collected between August and December. Even with the extended summer/fall season, multivariate ordination indicated seasonal variability in this subregion (Figure 28).

Due to seasonal differences, two target indices were calculated based on seasonality. Most metrics indicated a more diverse and less tolerant community structure in the summer/fall index period (Figure 29).

Index ranges in this subregion are based on only six samples from three stations. Additional samples from existing sites as well as additional sites are needed to strengthen the index calculations.

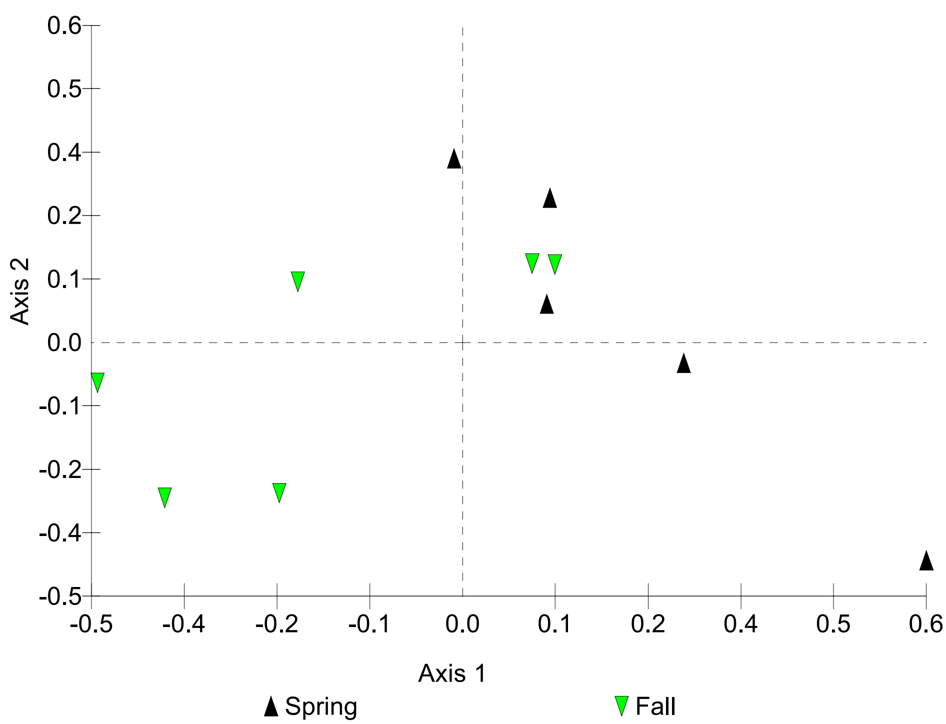


Figure 28: MDS ordination of spring and fall reference data in bioregion 67g. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at four sites.

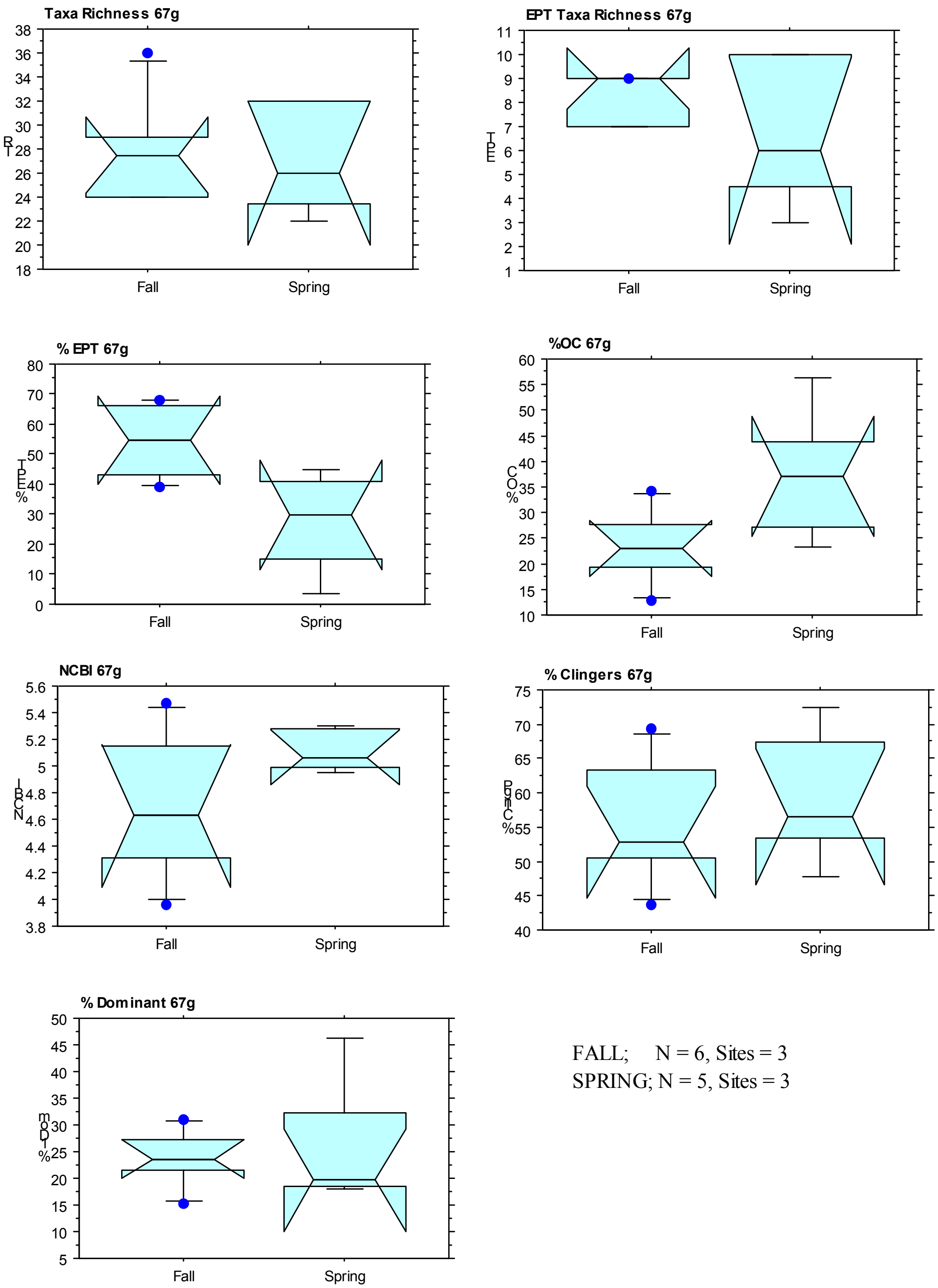


Figure 29: Distribution of reference data for individual biometrics by season in subregion 67g. Data represent multiple samples from four sites.

6.6 Seasonal Variability in Bioregion 68a.

Although there was some seasonal trending in bioregion 68a, it was not clearly defined (Figure 30). This may be a reflection of the extended spring sampling period with some samples being collected as late as June 30. Review of the individual metrics that make up the index also demonstrated significant overlap between seasons (Figure 31). Therefore, a single criterion to be applied year round was calculated for this region.

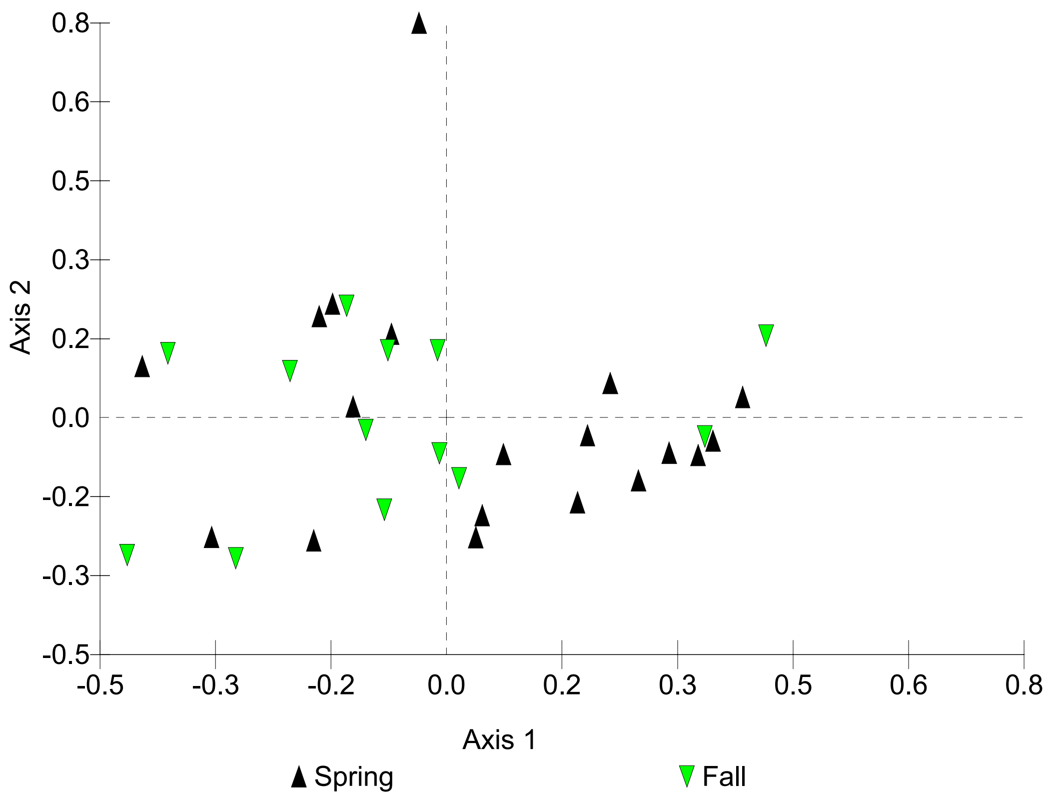


Figure 30: MDS ordination of spring and fall reference data in bioregion 68a. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at eight sites.

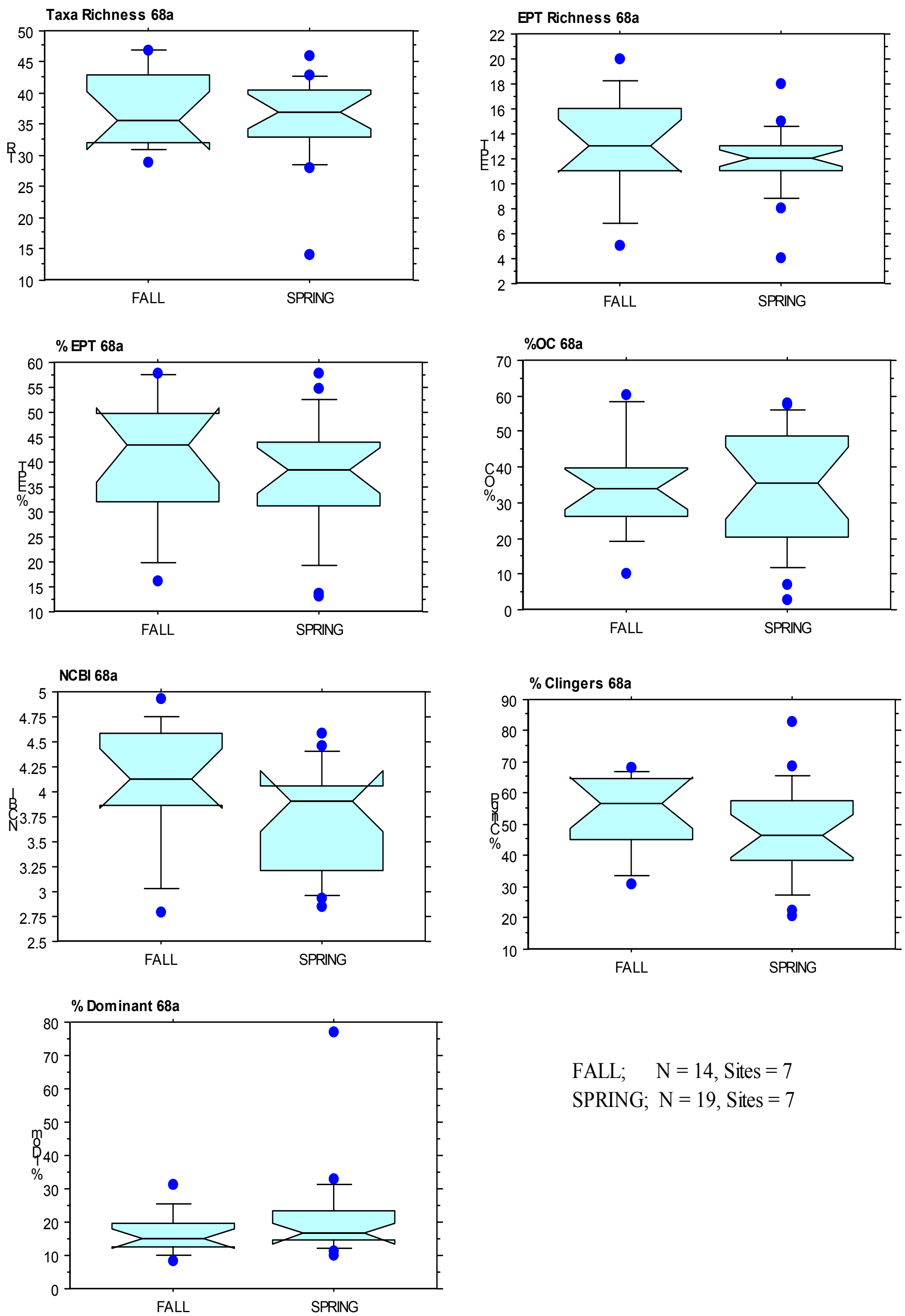


Figure 31: Distribution of reference data for individual biometrics in bioregion 68a. Data represent multiple samples from eight sites.

6.7 Seasonal Variability in Bioregion 68b.

A distinct seasonal difference was observable in bioregion 68b, the Sequatchie Valley (Figure 32). Many of these streams are dry in the fall, so the summer/fall sampling period is based on a limited number of samples. However, the reduced or non-existent flow furthers the case for seasonal biocriteria. Every biometric was more robust in the spring (Figure 33). Although biocriteria were proposed for both seasons, assessments would be most meaningful in the spring index period.

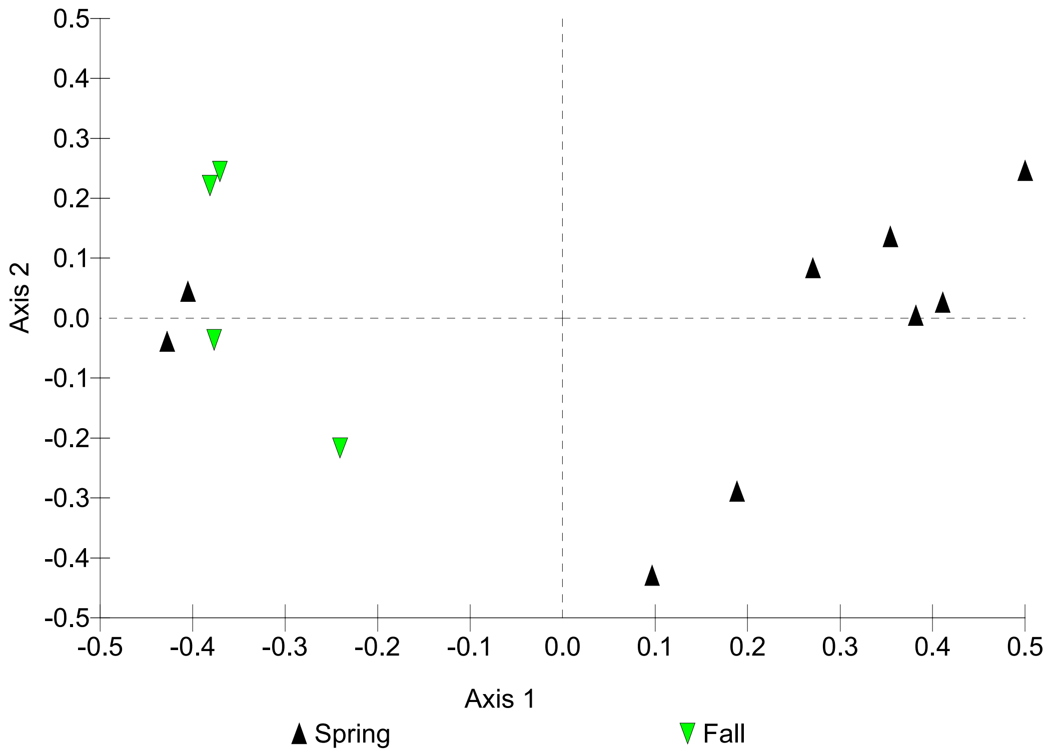


Figure 32: MDS ordination of spring and fall reference data in bioregion 68b. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at three sites.

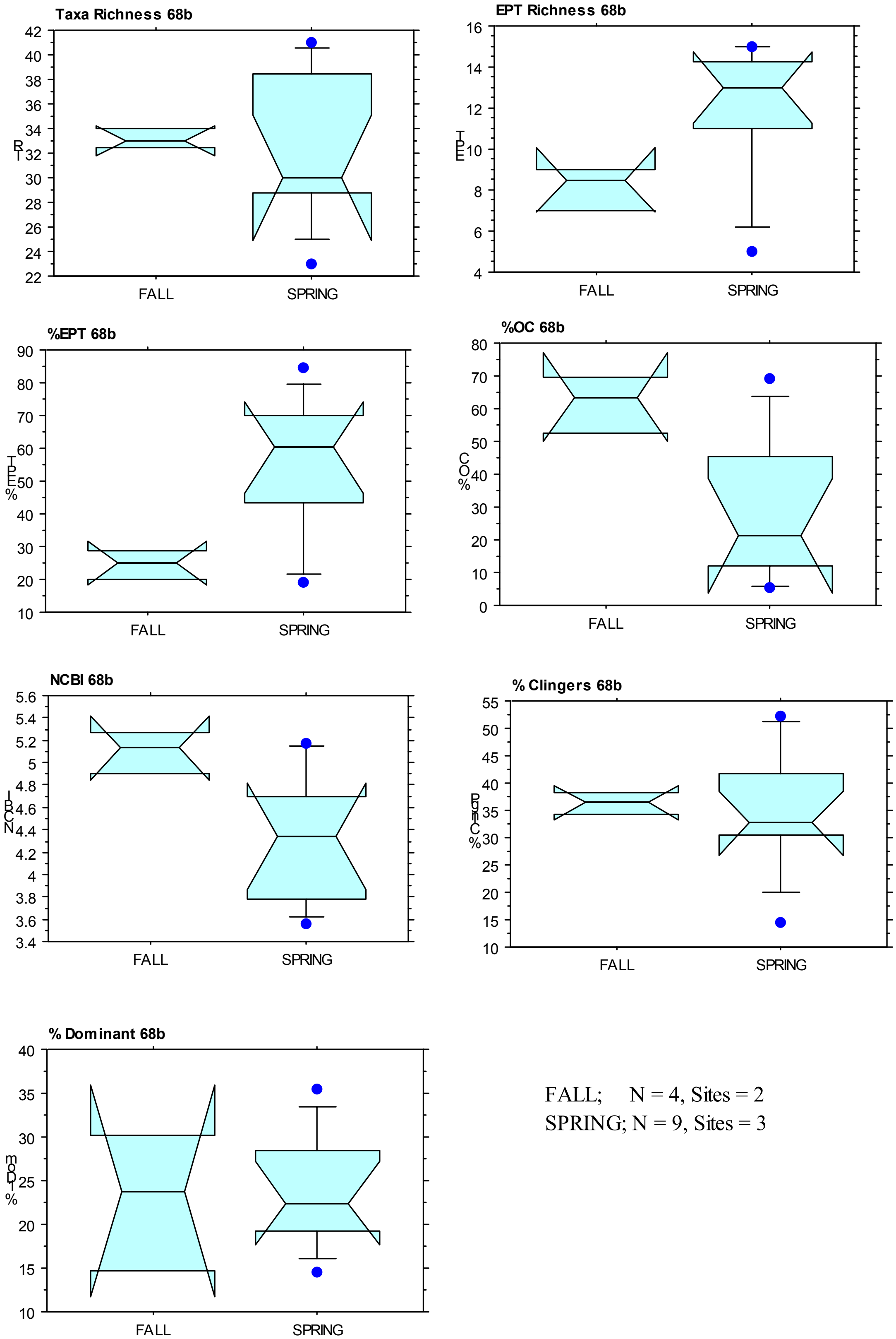


Figure 33: Distribution of reference data for individual biometrics by season in bioregion 68b. Data represent multiple samples from three sites.

6.8 Seasonal Variability in Bioregion 68c.

A distinct seasonal difference was also observed in bioregion 68c, the Plateau Escarpment (Figure 34). Although some metrics, especially richness metrics, scored higher in the spring, others were more robust in the fall (Figure 35). The target index score in the spring (32) is higher than the fall expectation (27). Although biocriteria were proposed for both seasons, samples collected during the spring period would be expected to demonstrate a more diverse benthic community and may be more meaningful in water quality assessments.

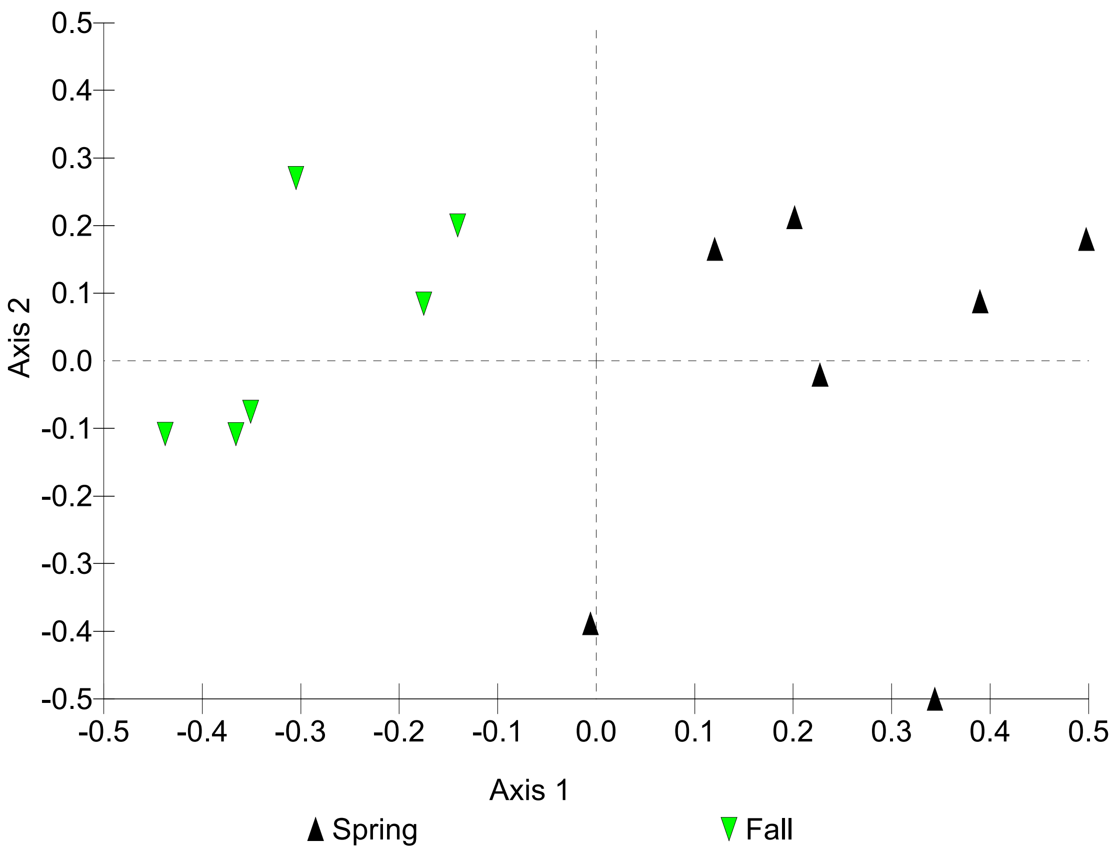


Figure 34: MDS ordination of spring and fall reference data in bioregion 68c. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at four sites.

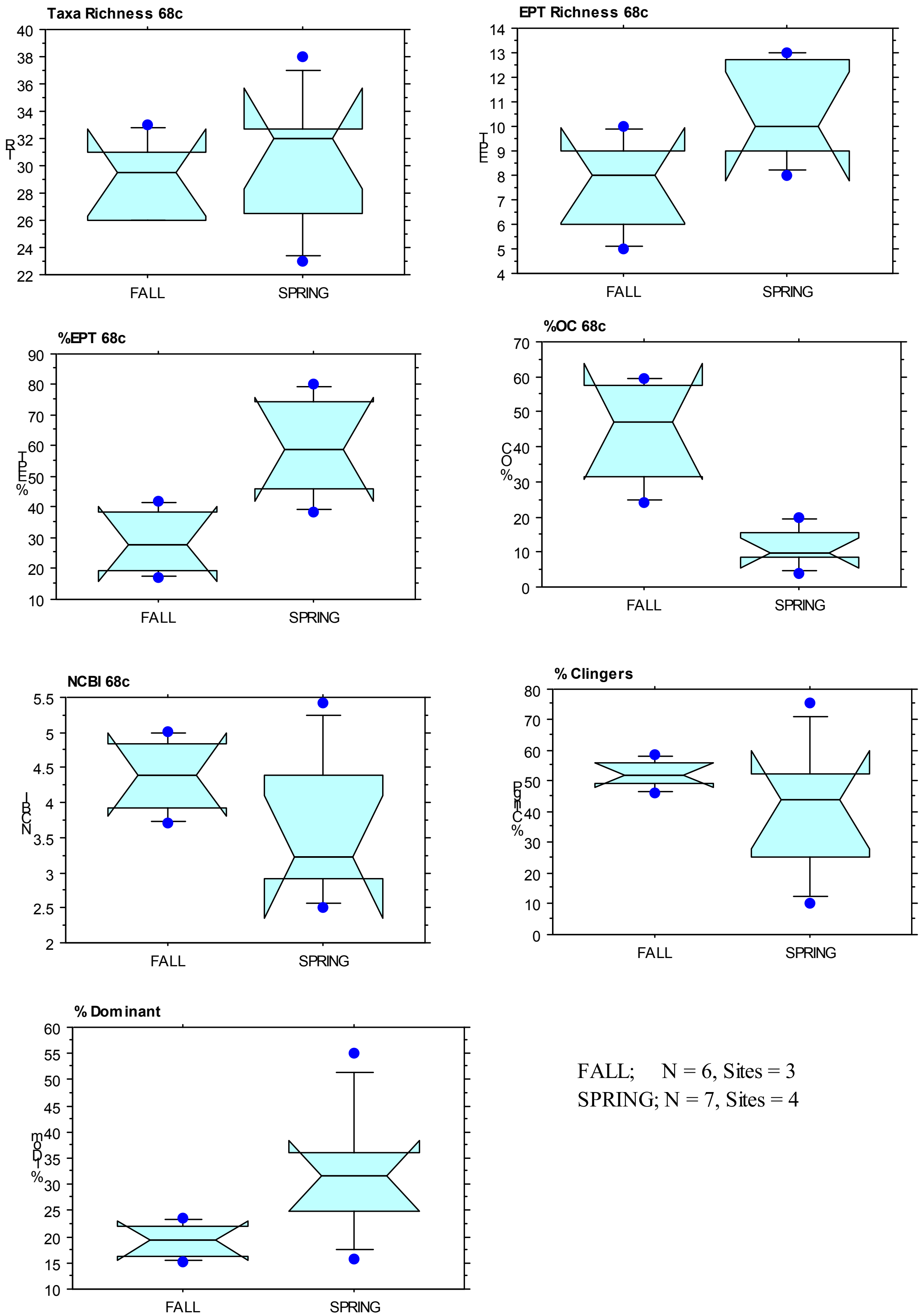


Figure 35: Distribution of reference data for individual biometrics in bioregion 68c. Data represent multiple samples from four sites.

6.9 Seasonal Variability in Bioregion 69d

A clear seasonal difference was observed in the benthic community between the spring and fall seasons in the Cumberland Mountains (Figure 36). Many of these streams become dry or are reduced to minimal flows in the fall. All metrics were more robust during the spring sampling period (Figure 37). Biocriteria were proposed for both seasons, however spring assessments may be more appropriate for evaluating the integrity of the macroinvertebrate community.

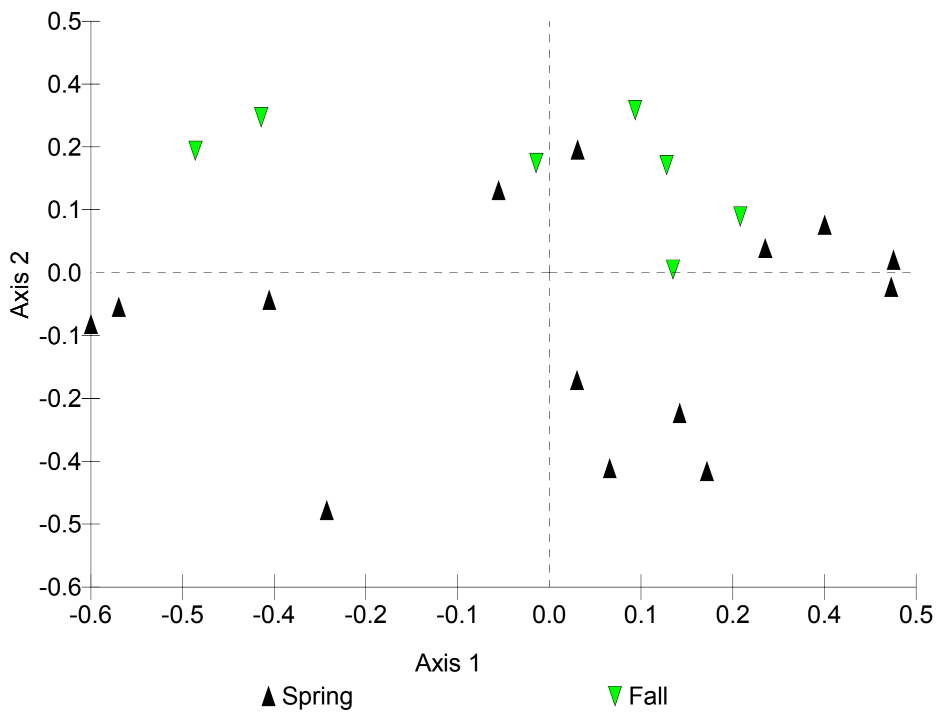


Figure 36: MDS ordination of spring and fall reference data in bioregion 69d. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at five sites.

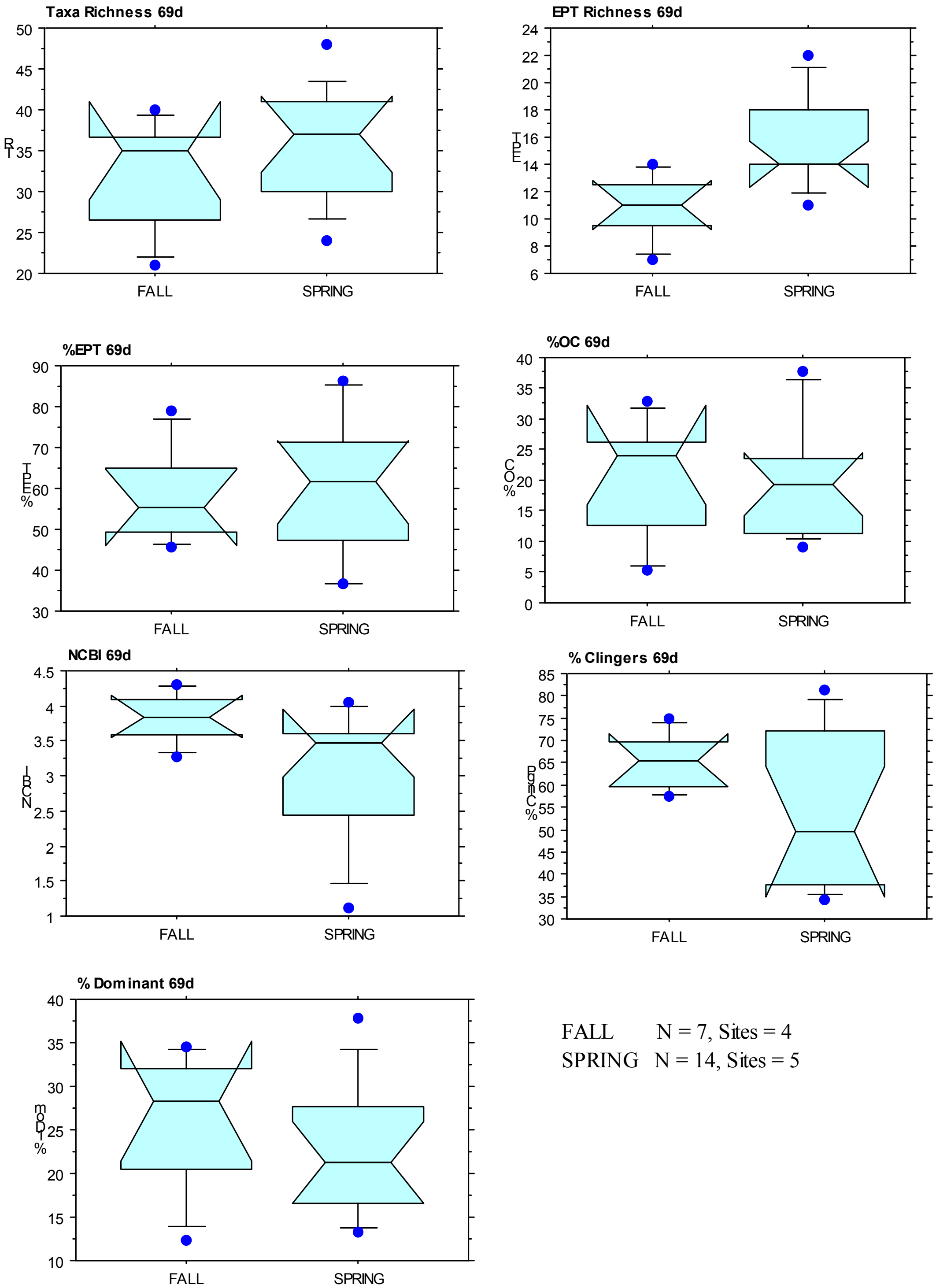


Figure 37: Distribution of reference data for individual biometrics by season in bioregion 69d. Data represent multiple samples from five sites.

6.10 Seasonal Variability in Bioregion 71e.

There appeared to be a tendency toward seasonal variation in the composition of macroinvertebrate communities in bioregion 71e, the Western Pennyroyal Karst (Figure 38). This may be misleading since the analysis is based on an insufficient number of data points. There were only two acceptable reference sites targeted in this region with 5 fall samples and six spring samples being collected.

Another problem in making definite seasonal determination in this region is the length of the spring sampling season. Samples were collected as late as June 29, which is usually a transition period in the benthic community.

Overall, index scores were equivalent for both seasons with reference streams typically scoring the maximum score of 42. Therefore, a single criterion applicable year-round was proposed for this region. Seasons may need to be separated at a later date if additional sampling and comparison to Kentucky reference data demonstrates a distinct seasonal difference in the macroinvertebrate community structure.

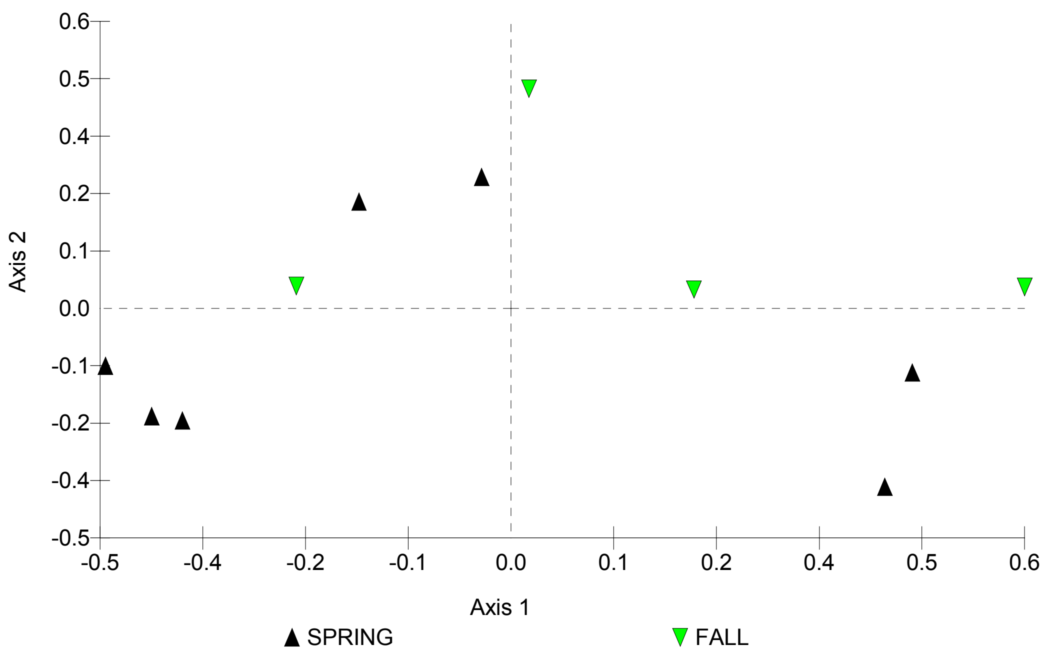


Figure 38: MDS ordination of spring and fall reference data in bioregion 71e. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samplings at two sites.

6.11 Seasonal Variability in Bioregion 71fgh.

There was not a distinct seasonal difference in the benthic community in the bioregion that included subregions 71f, g and h in the Interior Plateau (Figure 39). Although the 6-week seasonal sampling periods were not maintained, samples were close enough that any seasonal trends should have been apparent. Samples were collected over a 60-day period in both seasons. A single criterion that would be applicable year round was proposed for this bioregion.

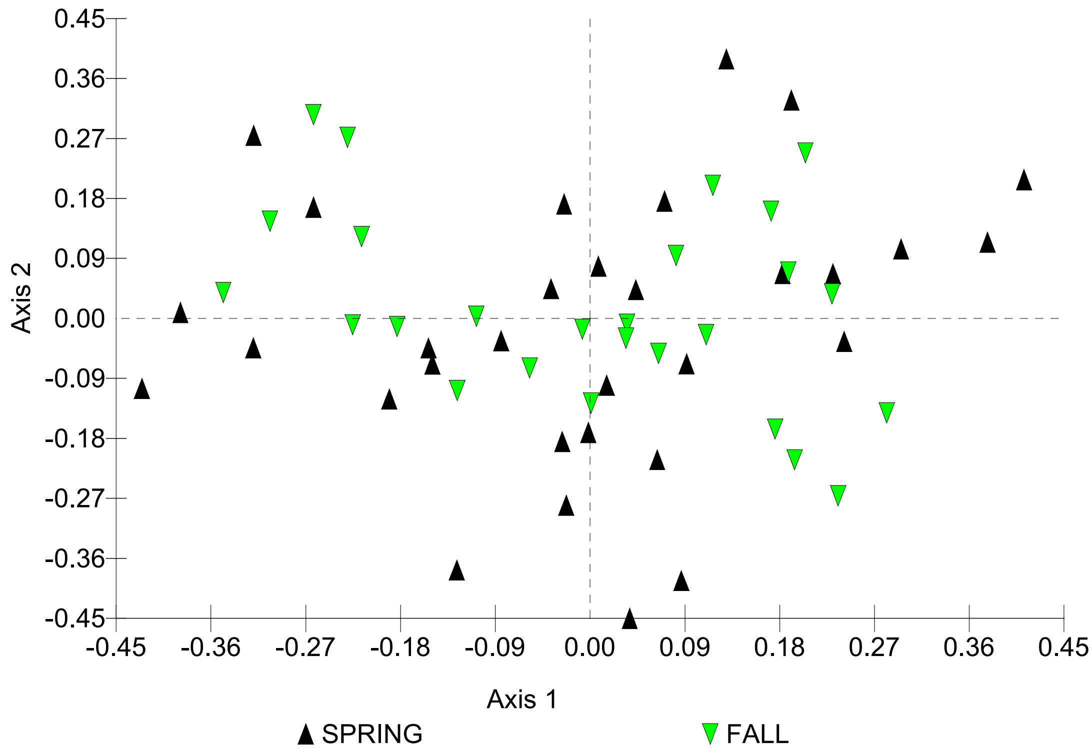


Figure 39: MDS ordination of spring and fall reference data in the bioregion that includes subregions 71f, 71g and 71h. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samplings at five sites in 71f and three sites each in 71g and 71h.

6.12 Seasonal Variability in Bioregion 71i.

Multivariate analysis of the Inner Nashville Basin (71i) demonstrated definite seasonal trends in both the kick and bank samples (Figure 40). Two separate target index scores were calculated for each sample type by season. Therefore, a series of four biocriteria were proposed for this region (Figure 41). Individual biometrics for both sample types were more robust in the spring (Figure 42). The late summer/fall season is naturally stressful on the benthos in this subregion as streams often go dry or habitat is unavailable as flow is reduced. For this reason, water quality assessments may be more appropriate in the spring.

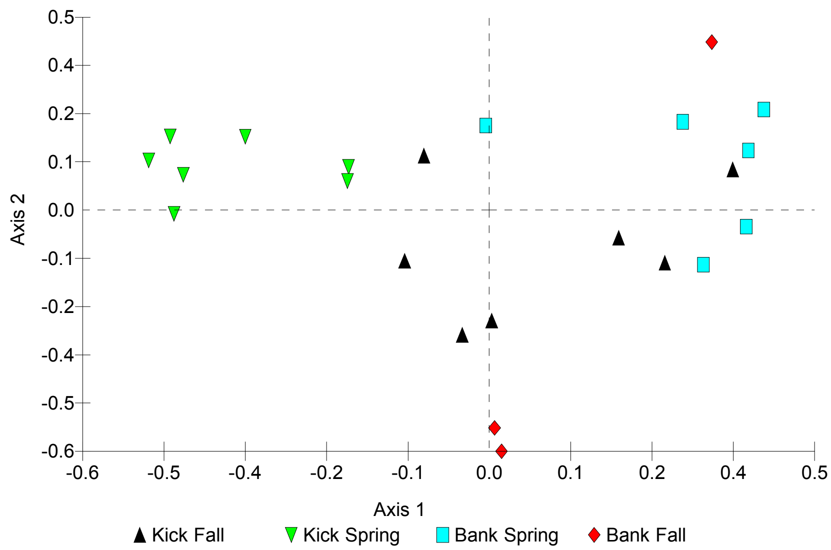


Figure 40: MDS ordination of spring and fall reference data in bioregion 71i. Data are segregated by sample type, kick or bank. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at seven kick sites and two bank sites.

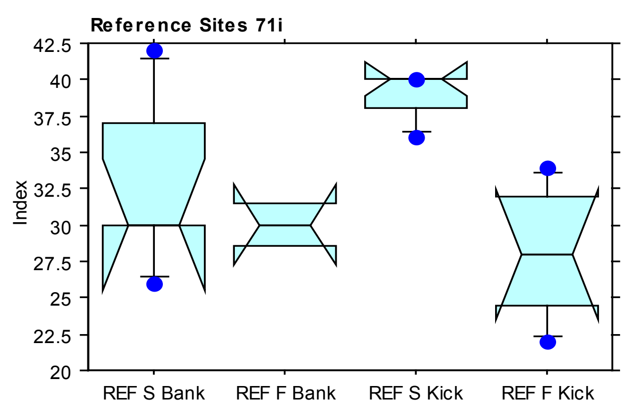


Figure 41: Comparison of reference multi-metric index scores by season and stream type in bioregion 71i (Inner Nashville Basin). "S" designates spring samples and "F" designates late summer/fall samples. Data represent multiple samples at seven sites for kick samples and two sites for bank samples.

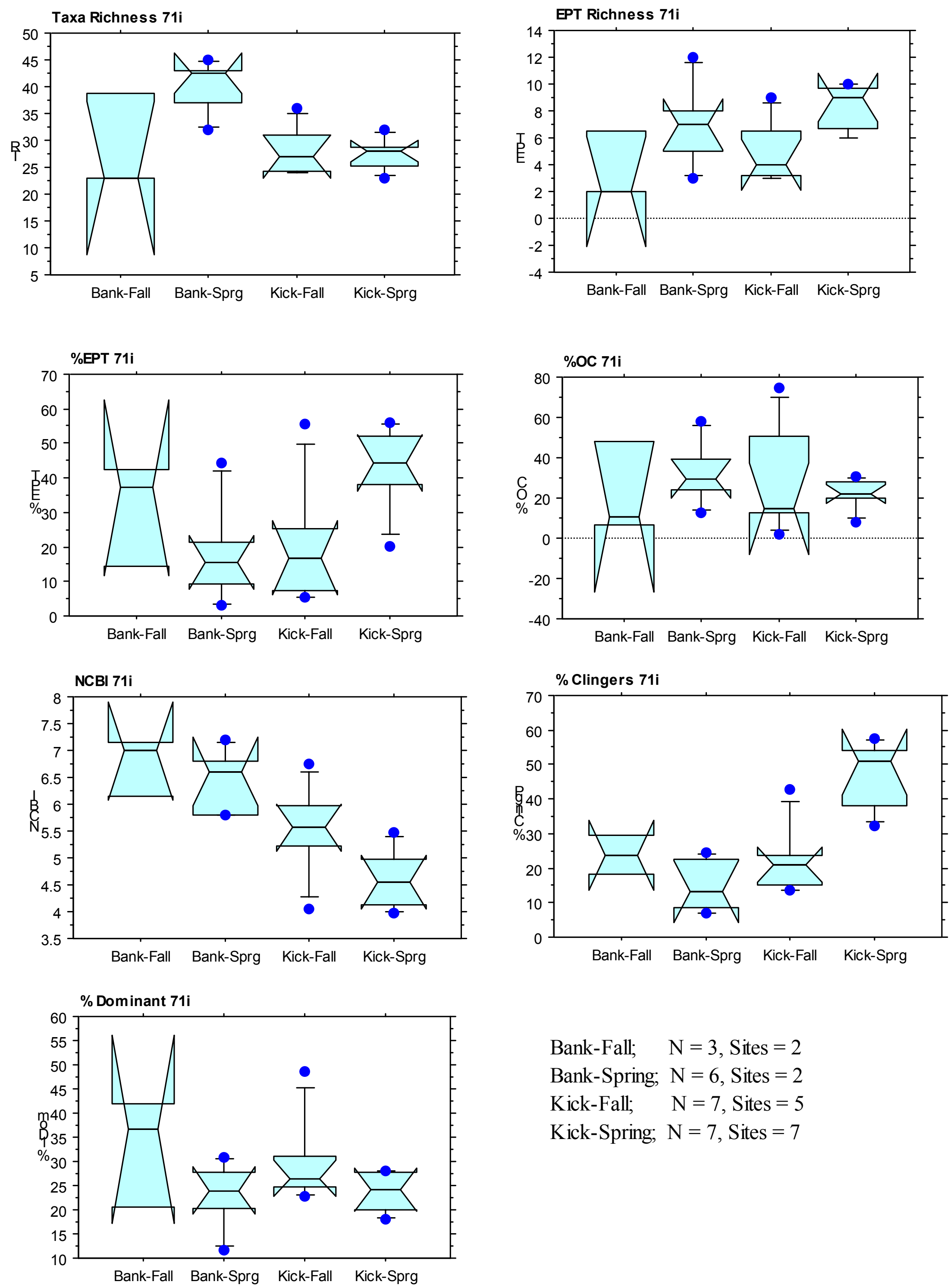


Figure 42: Distribution of reference data for individual biometrics by season in bioregion 71i. Data represent multiple samples over a 5-year period from seven sites for kick samples and two sites for bank samples.

6.13 Seasonal Variability in Bioregion 73a.

Seasonal comparison in the Northern Mississippi Alluvial Plain (73a) demonstrated some seasonal trending, although there was overlap (Figure 43). Sites in this region were collected within recommended seasonal windows (6 weeks or less). However, due to the limited number of sites and the small number of sampling episodes in each season, a clear evaluation of seasonal differences cannot be made. Therefore, data for both seasons were combined for development of expected metric ranges. These may later be split by season if additional sampling confirms seasonal variation.

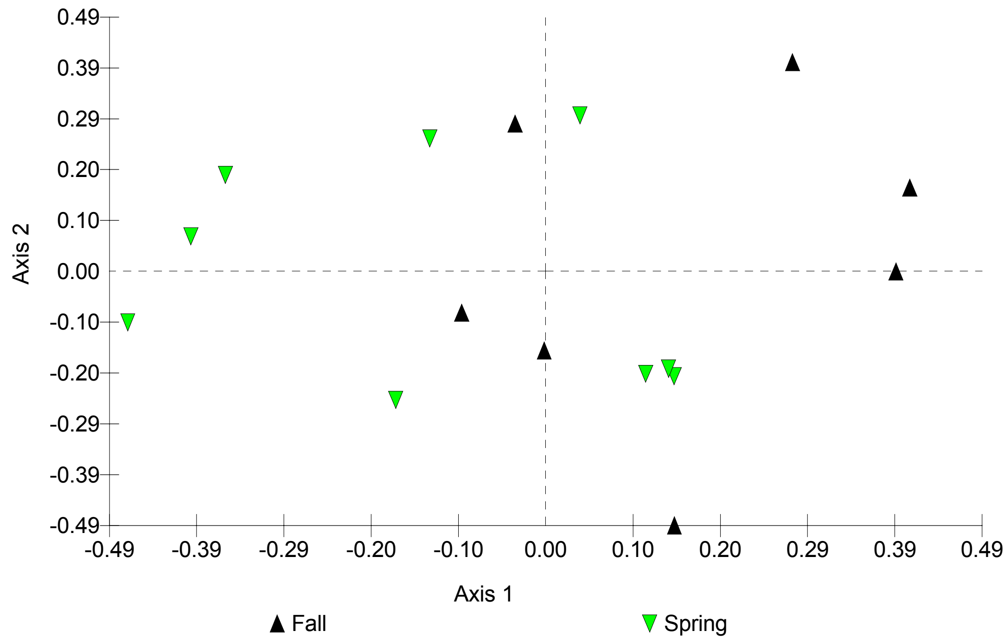


Figure 43: MDS ordination of spring and fall reference data in bioregion 73a. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at four sites.

6.14 Seasonal Variability in Bioregion 74a.

There was a distinct seasonal difference in the macroinvertebrate community in bioregion 74a (Figure 44). A more diverse and stable benthic community was present in late summer/fall samples than those collected in the spring. Each of the seven metrics was significantly better in the fall samples (Figure 45). Therefore, biological criteria were divided into two target index scores based on season. A score of 32 would represent 75% of reference condition in late summer/fall (July-November). A lower index score of 27 would represent 75% of reference condition in the spring (February-June).

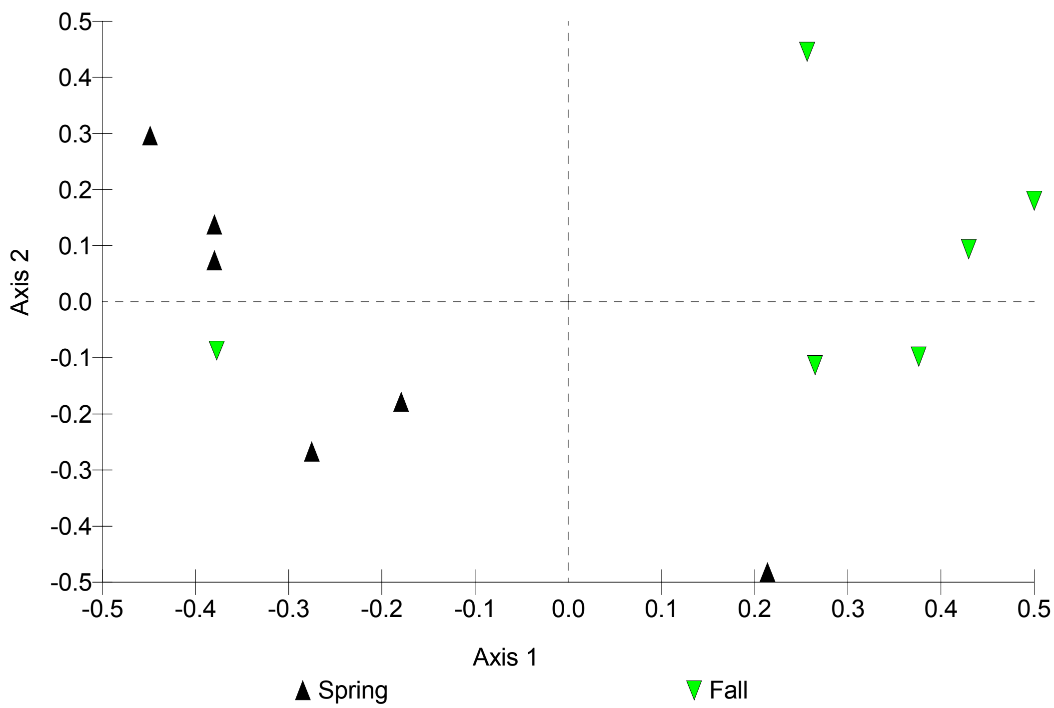


Figure 44: MDS ordination of spring and fall reference data in bioregion 74a. Plot is based on multivariate analysis of seven biometrics for each sample. Data represent multiple samples at two sites.

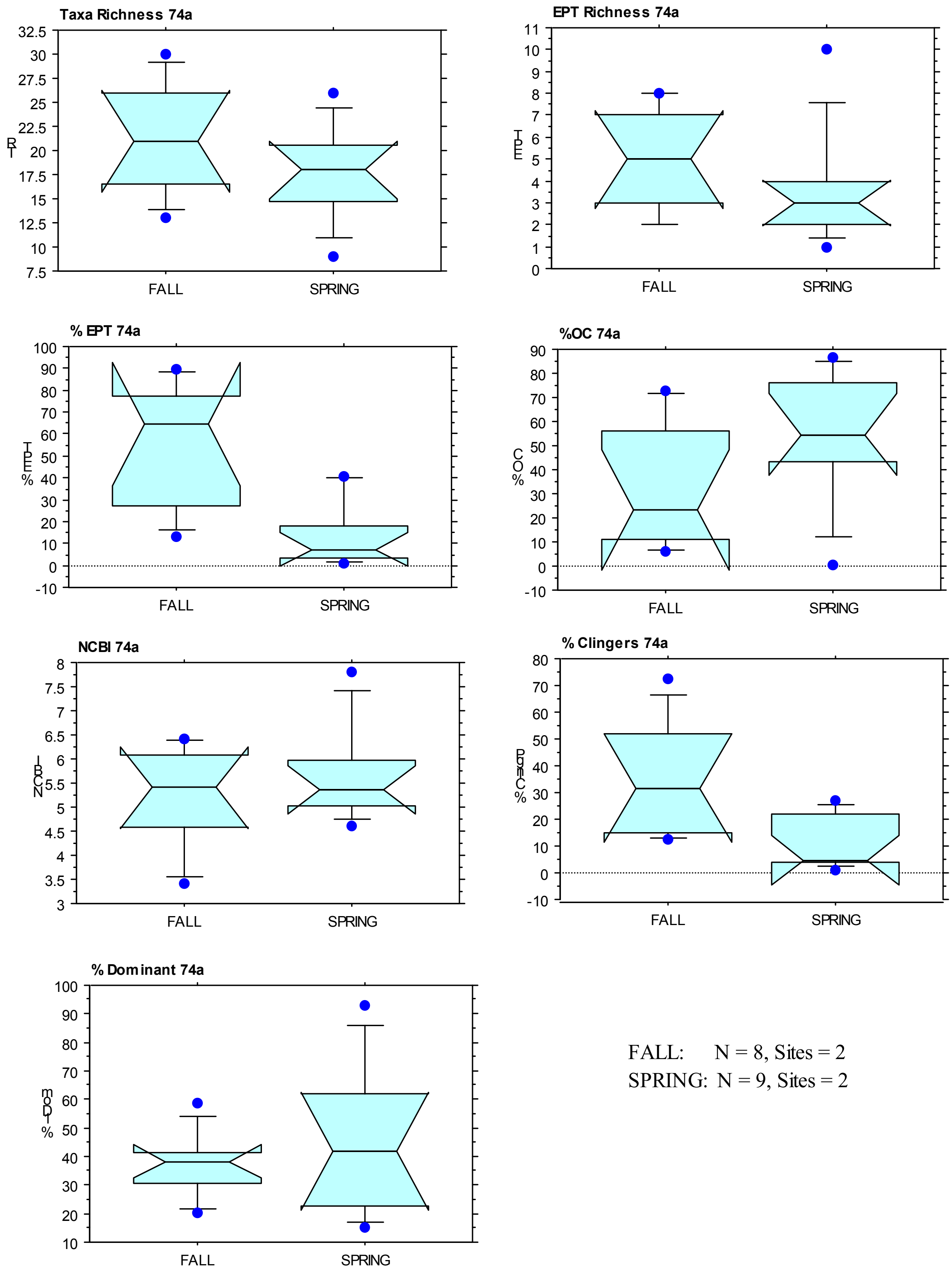


Figure 45: Distribution of reference data for seven biometrics by season in bioregion 74a. Data represent multiple samples from two sites.

7. CALIBRATING A BIOLOGICAL INDEX FOR ASSESSING STREAM CONDITION IN TENNESSEE BIOREGIONS

The proposed biocriteria indices were determined by a quadrisection of the data of each metric at the 90^{th} or 10^{th} percentile (depending on direction of the metric) in each bioregion (Table 3). Separate indices were calculated by season or sample type within bioregions if appropriate.

The following procedure was used to develop the proposed criteria index:

1. The 90^{th} or 10^{th} percentile, depending on the direction of response for the metric, was selected as the value representative of reference conditions for each metric.

2. The data were then quadrisected at the 90^{th} or 10^{th} percentile as the upper bounds.

   For metrics that were expected to decrease with increased pollution (TR, EPT, %EPT, %Clingers):

   $$\text{Range (expected decrease)} = \frac{90^{th}\text{ percentile} - \text{possible minimum value for metric}}{4}$$

   For metrics that were expected to increase with increased pollution (%OC, NCBI, %Dominant):

   $$\text{Range (expected increase)} = \frac{\text{possible maximum value for metric} - 10^{th}\text{ percentile}}{4}$$

5. Metrics were equalized by assigning numbers (6, 4, 2, 0) to the quadrisected data (Figure 46). These are not exact quarters, since a value of six could be assigned to values outside of the 90^{th} or 10^{th} percentile that was used for quadrisection of the data. Six is equivalent to the expectations of reference condition (or better).

   6 = upper quarter plus values outside of 90^{th} (or 10^{th}) percentile
   4 = 2^{nd} quarter within 90^{th} (or 10^{th}) percentile
   2 = 3^{rd} quarter within 90^{th} (or 10^{th}) percentile
   0 = bottom quarter within 90^{th} (or 10^{th}) percentile

4. The seven metrics were combined to come up with a single, multi-metric index. The maximum possible score was based on the maximum reference score for each bioregion and was not always equal to the maximum possible index score of 42.

6. Target index scores (biocriteria) were set at 75% of the possible reference score for each bioregion. This was considered to represent 75% of the expectation for reference condition.

7. Target index scores (biocriteria) were adjusted by season for regions that had distinctly different benthic populations between seasons as determined by multivariate ordination. Figure 47 illustrates metric scores between seasons. These are not exact quarters, since a value of six could be assigned to values outside of the 90^{th} percentile range that was used for quadrisection of the data.

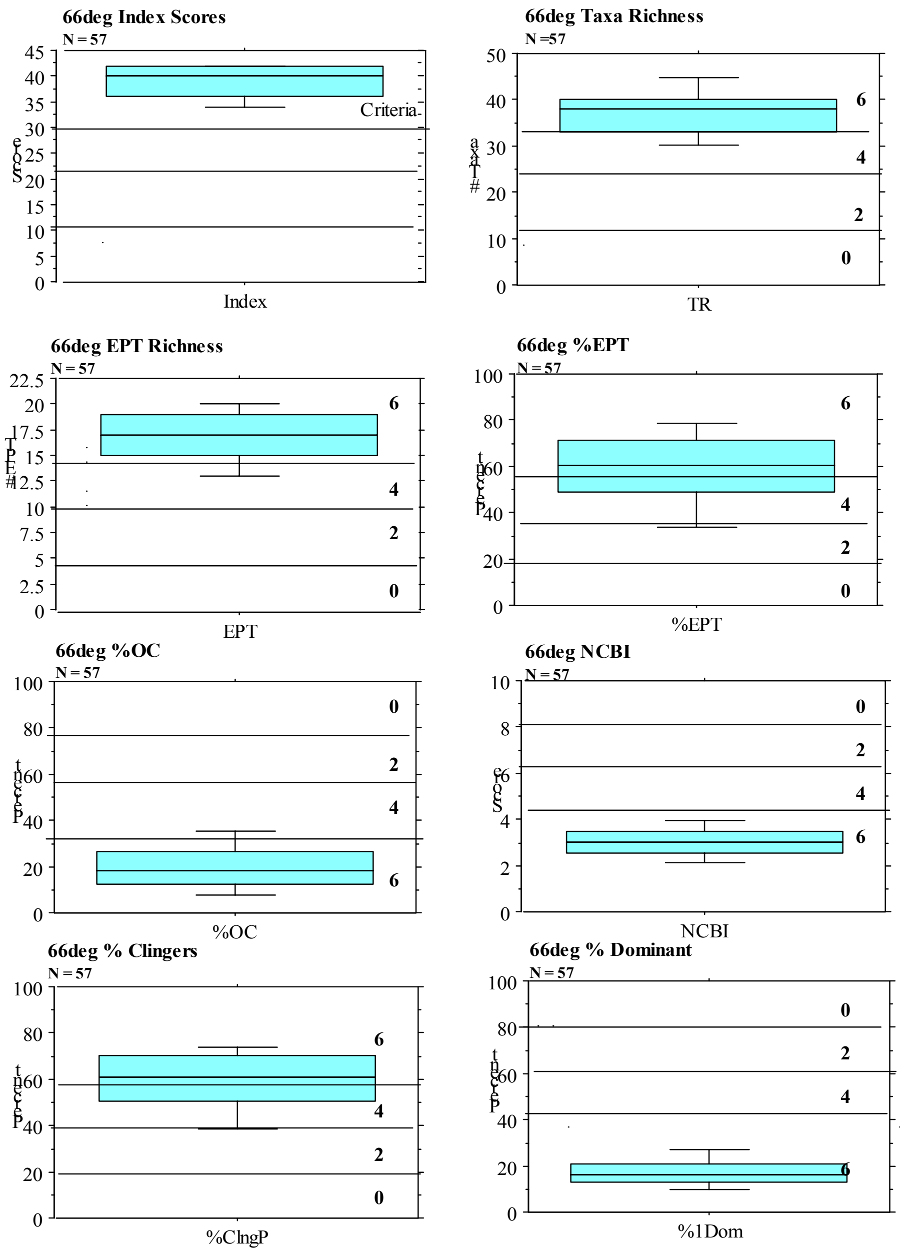
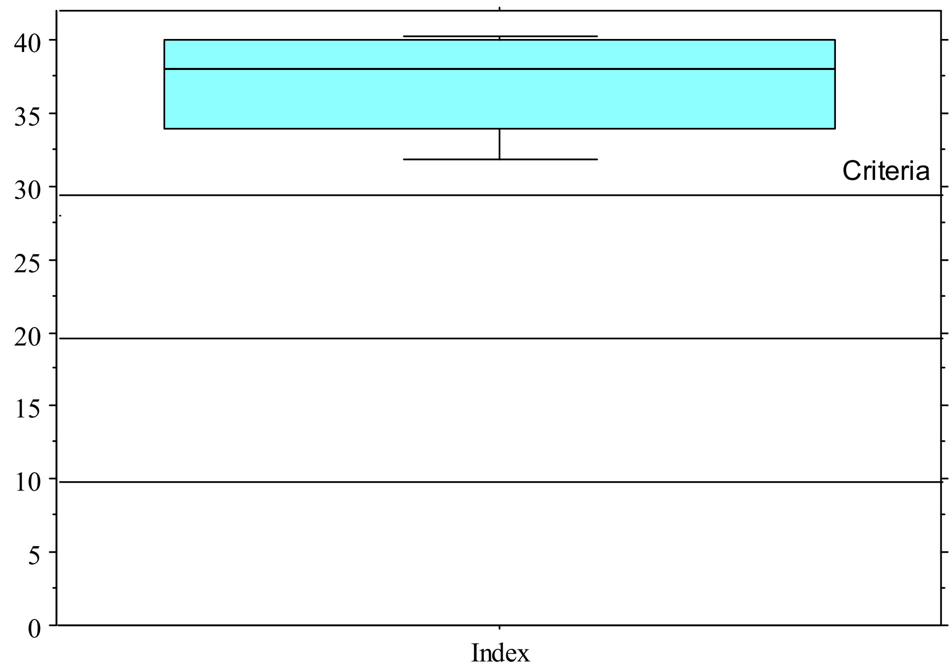


Figure 46: Reference site biometric and total index scores in bioregion 66deg. Left axis represents total range of scores possible for metric. Horizontal lines represent scoring break-offs for each category. They do not represent equal quarters since a score of six is possible at values outside of the 10^{th}-90^{th} percentile range that was used for quadrisection of data. Scoring criteria can be found in Table 5.

Ecoregion 69d: Spring Index Quadrisection
N = 14



Ecoregion 69d: Fall Index Quadrisection
N = 7

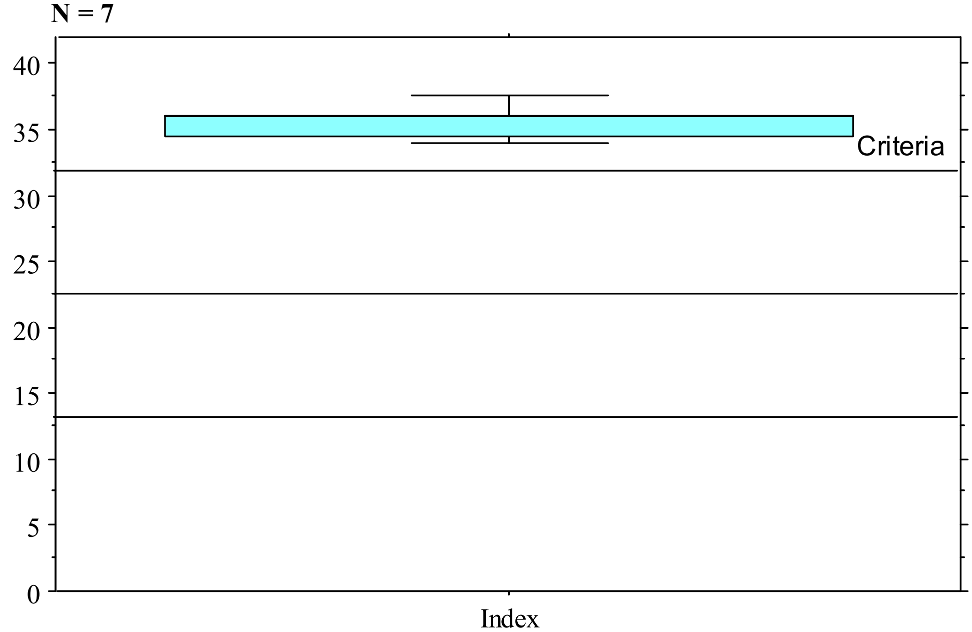


Figure 47: Proposed biocriteria index scores by season at five reference sites (multiple samples) in bioregion 69d. Lines represent quadrisection of data.

Table 3: Scoring criteria and target index scores by bioregion.

Bioregion: 65abei - 74b **Target Index Score (January - December) = 32**			**Method = SQBANK** **Stream Order = 2, 3, 4** **(includes non-wadeable)**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 37	25 - 37	12 – 24	< 12
EPT Richness (EPT)	> 9	7 – 9	3 – 6	< 3
% EPT	> 35.7	23.9 – 35.6	12 – 23.8	< 12
% OC	< 44.1	44.1 – 62.7	62.8 – 81.4	> 81.4
NCBI	< 5.90	5.90 – 7.20	7.21 – 8.60	> 8.60
% Dominant	< 35.1	35.1 – 56.7	56.8 – 78.3	> 78.3
% Clingers	>29.9	20.0 – 29.9	10.0 – 19.9	< 10.0

Descriptive Statistics **n = 98**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	10.0	26.0	38.5	50.0	56.0
EPT Richness (EPT)	1.0	5.0	8.0	13.0	16.0
% EPT	4.4	11.5	23.8	47.7	81.6
% OC	14.5	25.3	48.4	70.5	77.9
NCBI	3.37	4.40	5.79	6.42	7.28
% Dominant	9.5	13.4	23.5	37.5	58.5
% Clingers	2.1	8.7	21.0	40.0	76.7

Bioregion 65j **Target Index Score (January - December) = 30**			**Method = SQKICK** **Stream Order = 2, 3**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 37	26 – 37	15 – 25	< 15
EPT Richness (EPT)	> 10	7 – 10	4 – 6	< 4
% EPT	> 47.1	31.4 – 47.1	15.6 – 31.3	< 15.6
% OC	< 36.7	36.7 – 57.8	57.9 – 79.0	> 79.0
NCBI	< 4.65	4.65 – 6.42	6.42 – 8.20	> 8.20
% Dominant	< 34.5	34.5 – 56.2	56.3 – 78.0	>78.0
% Clingers	> 47.1	31.4 – 47.1	15.6 – 31.3	< 15.6

Descriptive Statistics **N = 23**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	22.0	25.0	33.0	45.8	49.0
EPT Richness (EPT)	6.0	6.8	12.0	14.4	18.0
% EPT	7.9	22.4	43.1	63.0	67.6
% OC	10.4	15.4	34.2	59.7	66.8
NCBI	2.76	2.86	4.04	4.80	5.53
% Dominant	10.4	12.6	18.3	38.8	43.9
% Clingers	18.8	26.4	41.8	63.0	71.5

Bioregion 66deg **Target Index Score (January – December) = 32**			**Method = SQKICK** **Stream Order = 1, 2, 3, 4**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 33	22 – 33	11 – 21	< 11
EPT Richness (EPT)	> 14	10 – 14	5 – 9	< 5
% EPT	> 58.0	39.2 – 58.0	19.6 – 39.1	< 19.6
% OC	< 31.2	31.2 – 54.1	54.2 – 77.1	> 77.1
NCBI	< 4.11	4.11 – 6.06	6.07 – 8.02	> 8.02
% Dominant	< 32.5	32.5 – 54.9	55.0 – 77.4	> 77.4
% Clingers	> 55.3	36.9- 55.3	18.4 – 36.8	< 18.4

Descriptive Statistics **N = 57**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	24.0	30.2	38.0	44.8	50.0
EPT Richness (EPT)	10.0	13.0	17.0	20.0	22.0
% EPT	26.2	33.9	60.6	78.7	97.0
% OC	0.0	8.1	18.4	35.6	62.0
NCBI	1.45	2.14	3.02	3.94	4.45
% Dominant	6.1	9.9	16.0	27.2	36.8
% Clingers	24.9	38.8	60.7	73.9	85.8

Bioregion 66f **Target Index Score (February – June) = 32** **Target Index Score (July – November) = 30**			**Method = SQKICK** **Stream Order = 1, 2, 3, 4**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 32	22 – 32	11 - 21	< 11
EPT Richness (EPT)	> 15	11 – 15	5 - 10	< 5
% EPT	> 60.2	40.2 – 60.2	20.1 – 40.1	< 20.1
% OC	< 30.3	30.3 – 53.5	53.6 – 76.8	> 76.8
NCBI	< 4.02	4.02 – 6.02	6.03 – 8.01	> 8.01
% Dominant	< 33.9	33.9 – 55.8	55.8 – 77.8	> 77.8
% Clingers	> 62.1	41.4 – 62.1	20.6 – 41.3	< 20.6

Descriptive Statistics **N = 11**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	21.0	25.2	32.0	43.4	47.0
EPT Richness (EPT)	9.0	9.6	16.0	21.4	22.0
% EPT	44.9	45.6	56.9	80.4	82.9
% OC	6.3	6.9	10.8	25.0	31.6
NCBI	1.83	2.01	2.58	3.62	3.83
% Dominant	11.8	11.8	19.2	26.6	31.7
% Clingers	35.4	37.4	68.4	83.0	83.9

Bioregion 67fhi Target Index Score (January – December) = 32			Method = SQKICK Order = 1, 2, 3, 4, 5	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 30	21 – 30	10 – 20	< 10
EPT Richness (EPT)	> 11	8 – 11	4 – 7	< 4
% EPT	> 44.7	29.8 – 44.7	14.8 – 29.7	< 14.8
% OC	< 27.0	27.0 – 51.3	51.4 – 75.7	> 75.7
NCBI	< 4.69	4.69 – 6.46	6.47 – 8.24	> 8.24
% Dominant	< 34.8	34.8 – 56.5	56.6 – 78.3	> 78.3
% Clingers	> 54.1	36.1 – 54.1	18.0 – 36.0	< 18

Descriptive Statistics N = 51					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	20.0	23.0	30.0	41.0	49.0
EPT Richness (EPT)	7.0	8.0	12.0	16.0	21.0
% EPT	17.1	27.3	44.2	59.8	75.3
% OC	1.1	2.6	13.4	31.5	65.0
NCBI	1.89	2.90	4.04	4.65	5.81
% Dominant	9.7	12.9	20.6	35.7	57.9
% Clingers	20.2	39.9	59.0	72.3	83.4

Bioregion 67g Target Index Score (February – June) = 28 Target Index Score (July – December) = 32			Method = SQKICK Order = 3, 4	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 24	17 – 24	8 - 16	< 8
EPT Richness (EPT)	> 7	5 – 7	2 - 4	< 2
% EPT	> 50.1	33.5 – 50.1	16.8 – 33.4	< 16.8
% OC	< 37.6	37.6 – 58.3	58.3 – 79.1	> 79.1
NCBI	< 5.64	5.46 – 7.09	7.10 – 8.55	> 8.55
% Dominant	< 37.7	37.7 – 58.4	58.5 – 79.2	> 79.2
% Clingers	> 52.8	35.3 – 52.8	17.7 – 35.2	< 17.7

Descriptive Statistics N = 11					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	22.0	23.2	27.0	33.6	36.0
EPT Richness (EPT)	3.0	4.2	9.0	10.0	10.0
% EPT	3.6	12.8	43.2	66.9	68.2
% OC	12.8	16.7	27.7	46.3	56.4
NCBI	3.96	4.17	5.00	5.37	5.47
% Dominant	15.2	16.8	22.1	37.2	46.4
% Clingers	43.7	46.1	55.2	70.5	72.4

Bioregion 68a **Target Index Score (January – December) = 32**			**Method = SQKICK** **Order = 2, 3, 4, 5**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 33	23 – 33	12 – 22	< 12
EPT Richness (EPT)	> 13	9 – 13	4 – 8	< 4
% EPT	> 41.4	27.7 – 41.4	13.9 – 27.6	< 13.9
% OC	< 38.0	38.0 – 58.6	58.7 – 79.3	> 79.3
NCBI	< 4.75	4.75 – 6.50	6.51 – 8.26	> 8.26
% Dominant	< 33.1	33.1 – 55.4	55.5 – 77.8	> 77.8
% Clingers	> 50.1	33.4 – 50.1	16.6 – 33.3	< 16.6

Descriptive Statistics **N = 33**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	14.0	29	36.0	46.0	47.0
EPT Richness (EPT)	4.0	7.8	12.0	18.0	20.0
% EPT	13.2	19.4	39.0	55.3	57.8
% OC	2.7	17.2	35.1	57.5	60.2
NCBI	2.79	2.98	4.01	4.61	4.94
% Dominant	8.2	10.6	16.0	29.6	76.9
% Clingers	20.7	33.3	50.2	67.0	83.0

Bioregion 68b **Target Index Score (February – June) = 26** **Target Index Score (July – November) = 30**			**Method = SQKICK** **Order = 2, 3**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 30	20 – 30	10 – 19	< 10
EPT Richness (EPT)	> 10	7 – 10	4 - 6	< 4
% EPT	> 55.9	37.4 – 55.9	18.8 – 37.3	< 18.8
% OC	< 29.7	29.7 – 53.1	53.2 – 76.6	> 76.6
NCBI	< 5.26	5.26 – 6.83	6.84 – 8.41	> 8.41
% Dominant	< 35.5	35.5 – 57.0	57.1 – 78.6	> 78.6
% Clingers	> 37.4	25.0 – 37.4	12.5 – 24.9	< 12.5

Descriptive Statistics **N = 13**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	23.0	27.0	32.0	40.2	41.0
EPT Richness (EPT)	5.0	5.8	12.0	15.0	15.0
% EPT	17.1	18.8	49.7	74.6	84.6
% OC	5.3	6.1	42.0	69.5	70.5
NCBI	3.56	3.67	4.56	5.24	5.31
% Dominant	10.8	13.8	22.4	32.0	35.4
% Clingers	14.5	25.6	34.6	50.0	52.3

Subregion 68c **Target Index Score (February – June) = 27** **Target Index Score (July – November) = 32**			**Method = SQKICK** **Order = 1, 2**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 25	17 – 25	9 - 16	< 9
EPT Richness (EPT)	> 9	7 – 9	3 - 6	< 3
% EPT	> 57.1	38.1 – 57.1	19.0 – 38.0	< 19.0
% OC	< 30.7	30.7 – 53.8	53.9 – 77.0	> 77.0
NCBI	< 4.58	4.58 – 6.38	6.39 – 8.19	> 8.19
% Dominant	< 36.9	36.9 – 57.9	58.0 – 79.0	> 79.0
% Clingers	> 46.3	30.9 - 46.3	15.4 – 30.8	< 15.4

Descriptive Statistics **N = 13**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	23	25	31	34	38
EPT Richness (EPT)	5	6	9	13	13
% EPT	17.3	18.8	41.9	76.3	80.4
% OC	3.8	7.4	19.8	57.8	59.7
NCBI	2.50	2.76	3.92	5.10	5.42
% Dominant	15.3	15.7	23.5	40.4	55.1
% Clingers	10.2	19.8	49.5	61.9	75.5

Bioregion 69d **Target Index Score (February – June) = 28** **Target Index Score (July – November) = 32**			**Method = SQKICK** **Order = 2, 3**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 31	21 – 30	11 - 20	< 11
EPT Richness (EPT)	> 14	10 – 14	5 - 9	< 5
% EPT	> 61.9	41.4 – 61.9	20.8 – 41.3	< 20.8
% OC	< 31.9	31.9 – 54.5	54.6 – 77.2	> 77.2
NCBI	< 3.82	3.82 – 5.87	5.88 – 7.93	> 7.93
% Dominant	< 35.3	35.3 – 56.8	56.9 – 78.4	> 78.4
% Clingers	> 57.2	38.1 – 57.2	19.0 – 38.0	< 19.0

Descriptive Statistics **N = 21**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	21	25	36	43	48
EPT Richness (EPT)	7	10	14	20	22
% EPT	36.6	37.8	59.3	82.6	86.2
% OC	5.2	9.1	20.8	34.3	37.8
NCBI	1.12	1.75	3.53	4.10	4.30
% Dominant	12.3	13.6	21.9	34.1	37.8
% Clingers	34.3	36.5	62.1	76.4	81.4

Bioregion 71e **Target Index Score (January – December) = 32**			**Method = SQKICK** **Order = 3**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 23	16 - 23	8 - 15	< 8
EPT Richness (EPT)	> 7	5 - 7	3 – 4	< 3
% EPT	> 48.9	32.7 – 48.9	16.4 – 32.6	< 16.4
% OC	< 26.7	26.7 – 51.1	51.2 – 75.6	> 75.6
NCBI	< 5.05	5.05 – 6.69	6.70 – 8.34	> 8.34
% Dominant	< 35.1	35.1 – 56.6	56.7 – 78.2	> 78.2
% Clingers	> 59.8	40.0 – 59.8	20.1 – 39.9	< 20.1

Descriptive Statistics **N =**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	19	20	29	32	32
EPT Richness (EPT)	4	5	9	11	11
% EPT	4.5	5.1	43.9	65.3	69.0
% OC	0.2	2.1	9.4	25.7	29.4
NCBI	3.26	3.39	4.38	4.89	4.98
% Dominant	12.7	13.4	23.1	45.9	48.5
% Clingers	32.0	40.0	65.4	79.8	85.2

Bioregion 71fgh **Target Index Score (January – December) = 32**			**Method = SQKICK** **Order = 2, 3, 4, 5**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 27	19 - 27	10 - 18	< 10
EPT Richness (EPT)	> 9	7 - 9	4 - 6	< 4
% EPT	> 53.38	35.9 – 53.8	18 – 35.8	< 18
% OC	< 27.5	27.5 – 51.6	51.7 – 75.8	> 75.8
NCBI	< 4.74	4.74 – 6.49	6.50 – 8.25	> 8.25
% Dominant	< 36.7	36.7 – 57.7	57.8 – 78.8	> 78.8
% Clingers	> 52.4	35.0 – 52.4	17.5 – 34.9	< 17.5

Descriptive Statistics **N = 57**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	15.0	22.4	30.0	37.6	43.0
EPT Richness (EPT)	7.0	8.2	11.0	14.0	18.0
% EPT	22.1	33.7	52.9	71.9	85.4
% OC	1.7	3.2	13.9	28.6	63.5
NCBI	2.15	2.97	4.10	5.21	5.73
% Dominant	11.4	15.5	22.9	35.8	49.4
% Clingers	21.4	34.0	50.6	70.0	84.2

Bioregion 71i **Target Index Score (February – June) = 30** **Target Index Score (July – November) = 26**			**Method = SQKICK** **Order = 3, 4**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 23	16 – 23	8 – 15	< 8
EPT Richness (EPT)	> 7	5 – 7	2 – 4	< 2
% EPT	> 41.5	27.7 – 41.5	13.8 – 27.6	< 13.8
% OC	< 30.5	30.5 – 53.6	53.7 – 76.8	> 76.8
NCBI	< 5.54	5.54 – 7.02	7.03 – 8.51	> 8.51
% Dominant	< 39.6	39.6 – 59.7	59.8 – 79.8	> 79.8
% Clingers	> 41.5	27.7 – 41.5	13.8 – 27.6	< 13.8

Descriptive Statistics **N = 14**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	23.0	23.9	27.5	32.4	36.0
EPT Richness (EPT)	3.0	3.0	6.5	10.0	10.0
% EPT	5.6	5.7	32.8	55.5	56.0
% OC	2.1	7.2	21.6	54.0	74.8
NCBI	3.97	4.04	5.11	6.12	6.74
% Dominant	18.1	19.3	26.4	33.3	48.7
% Clingers	13.5	13.6	34.8	55.5	57.4

Bioregion 71i **Target Index Score (February – June) = 32** **Target Index Score (July – November) = 24**			**Method = SQBANK** **Order = 3**	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 32	22 - 32	11 – 21	< 11
EPT Richness (EPT)	> 7	5 – 7	3 – 4	< 3
% EPT	> 33.2	22.2 – 33.2	11.1 – 22.1	< 11.1
% OC	< 30.9	30.9 – 53.9	54.0 – 77.0	> 77.0
NCBI	< 6.87	6.87 – 7.91	7.92 – 8.96	> 8.96
% Dominant	< 34.9	34.9 – 56.5	56.6 – 78.2	> 78.2
% Clingers	> 21.3	14.2 – 21.3	7.0 – 14.1	< 7.0

Descriptive Statistics **N = 9**					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	23.0	23.0	42.0	44.6	45.0
EPT Richness (EPT)	2.0	2.0	6.0	10.4	12.0
% EPT	2.9	4.4	17.0	44.4	44.4
% OC	5.6	7.7	26.6	59.5	60.7
NCBI	5.80	5.81	6.64	7.21	7.22
% Dominant	11.7	13.1	27.1	41.0	43.9
% Clingers	6.9	7.5	16.5	28.6	31.5

Bioregion 73a Target Index Score (January - December) = 21			Method = SQBANK Order = 3, 4 (Includes non-wadeable)	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 27	19 – 27	9 – 18	< 9
EPT Richness (EPT)*	NA	NA	NA	NA
% EPT	>25.5	17.0 – 25.5	8.0 – 16.9	< 8.0
% OC	<26.7	26.7 – 51.0	51.0 – 75.4	> 75.4
NCBI	<6.86	6.86 – 7.90	7.91 – 8.95	> 8.95
% Dominant	<36.7	36.7 – 57.7	57.8 – 78.8	> 78.8
% Clingers*	NA	NA	NA	NA

Descriptive Statistics N = 16					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	18.0	22.0	28.5	37.6	39.0
EPT Richness (EPT)	0.0	0.0	1.0	3.0	3.0
% EPT	0.0	0.0	3.2	34.2	38.3
% OC	1.7	2.2	23.3	40.3	56.1
NCBI	5.74	5.8	7.3	7.86	8.14
% Dominant	14.1	15.5	24.5	37.8	58.8
% Clingers	0.0	0.5	1.1	8.3	31.2

*EPT richness and % Clingers were not used for biocriteria development in this bioregion.

Bioregion 74a Target Index Score (February – June) =27 Target Index Score (July – November) = 32			Method = SQKICK Order = 2	
Metric	**6**	**4**	**2**	**0**
Taxa Richness (TR)	> 19	13 - 19	7 – 12	< 7
EPT Richness (EPT)	> 5	4 – 5	2 – 3	< 2
% EPT	> 61.3	41.0 – 61.3	20.6 – 40.9	< 20.6
% OC	< 30.0	30.0 – 53.3	53.4 – 76.7	> 76.7
NCBI	< 5.55	5.55 – 7.04	7.05 – 8.54	> 8.54
% Dominant	< 40.1	40.1 – 60.1	60.2 – 80.1	> 80.1
% Clingers	> 39.0	26.1 – 39.0	13.1 – 26.0	< 13.1

Descriptive Statistics N = 17					
Metric	**Minimum**	**10%**	**50%**	**90%**	**Maximum**
Taxa Richness (TR)	9.0	13.2	20.0	26.8	30.0
EPT Richness (EPT)	1.0	2.0	4.0	8.0	10.0
% EPT	1.2	2.1	23.4	81.8	89.7
% OC	0.6	6.5	47.6	80.8	86.7
NCBI	3.41	4.05	5.37	6.74	7.80
% Dominant	15.2	20.0	39	71.6	92.9
% Clingers	1.2	3.9	16.3	52.1	72.4

Note: Subregion 74b is included in Bioregion 65abei-74b

8. FIELD TESTING PROPOSED BIOCRITERIA

After metric ranges and target index scores were developed based on reference data, it was necessary to field test the proposed criteria to ensure that it was a fair and accurate method for assessing the health of the benthic community. This was done in three stages. First, the proposed criteria were tested against two alternative methods to gauge how well each method matched historic assessments at 60 stations in 10 ecological subregions (representing eight bioregions). The proposed method was the most consistent when compared with historic assessments.

Next, the proposed regional reference-based biocriteria were compared to both impaired and un-impaired test sites in six bioregions. The proposed biocriteria proved to be sensitive to moderate and high levels of pollution but did not indicate impairment when sites had previously been assessed as supporting a healthy benthic community. The proposed method also proved useful in defining the level of impairment in studies that had generated inconclusive findings due to impaired upstream reaches.

Finally, probabilistic monitoring data at fifty randomly selected streams in the Inner Nashville Basin were compared to the proposed biocriteria. Results were consistent with non-random watershed assessments in this region.

8.0 Comparison of the Proposed Biocriteria to Two Alternate Assessment Methods.

The multi-metric index proposed by the Division, as well as two other potential methods of setting biocriteria, were tested to see if the proposed index was the most effective tool for assessing the health of the benthic community. The three methods were applied to 60 test sites in 10 subregions representing eight bioregions (Table 4). All stations had been surveyed between 1993 and 2000 using single-habitat semi-quantitative techniques similar to the method used for developing the reference database. The sites represented stream segments that had been rated as having various levels of impairment as well as some that were considered to support a healthy benthic community. Various types of pollutants were represented including pathogens, nutrients, siltation, habitat alteration, organic enrichment, low dissolved oxygen and temperature elevation. (Table 4)

First, the Division tested the use of four individual metrics, patterned after the state of New York's biological impairment criteria (Bode and Novak, 1995). The single most responsive metric from each of the four categories was selected as a potential criterion. Metric selection protocol followed the steps outlined in section 3. The metrics that were determined to be the most responsive in each category were EPT, percent oligochaetes and chironomids (%OC), NCBI and percent clingers (%Clingers). The expected score for each metric was set at either the 90th percentile (OC% and NCBI) or the 10th percentile (EPT and % Clingers) of reference data depending on whether a metric was expected to increase or decrease relative to impact. The metrics were independently applied so that each could indicate impairment independent of the other three. The individual metric method proved overly sensitive.

Seventy-nine percent of streams that had been rated as supportive of fish and aquatic life using historic assessment methods were rated as being impaired when this method was applied to the data set (Table 4).

The second possible biocriteria evaluated was a multi-metric index based on a trisection of the reference data. The same seven metrics were used as in the Division's proposed multi-metric index outlined in this document. However, data were trisected instead of quadrisected at the 90^{th} (or 10^{th}) percentile. The upper third instead of the upper fourth of the data range was used to set the target index score. This method was not responsive to moderate levels of impairment. Of 33 sites that had previously been assessed as impaired, 70 percent would pass biocriteria based on a trisected index.

When compared to historic assessments at 60 sites in 10 subregions, the proposed quadrisected method of establishing biocriteria proved to be the most responsive to impairment of the three methods tested without being overly sensitive. Biological assessments based on the proposed quadrisected index matched the original assessment of biotic integrity at 84 percent of the stations. The criteria also helped clarify assessments in cases where upstream references were impaired.

Table 4: Comparison of previously assessed sites to proposed regional criteria

STATION	LEVEL IV SUB-REGION	ORIGINAL ASSESS-MENT	PROPOSED QUADRISECTED INDEX	TRISECTED INDEX	FOUR INDIVIDUAL METRICS
SHORT000.8BT	66G	IMPAIRED Habitat Pathogens	FAIL	PASS	FAIL
DAVIS024.1C	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	FAIL	FAIL
BLIME00.5WN	67F	SUPPORTING	PASS	PASS	FAIL
BLIME04.0WN	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	FAIL	FAIL
CAWOO00.2CL	67F	SUPPORTING	PASS	PASS	PASS
CROOK01.1BT	67F	SUPPORTING	PASS	PASS	FAIL
DAVIS022.6CL	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	FAIL	FAIL
DAVIS20.5CL	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	PASS	FAIL

STATION	LEVEL IV SUB-REGION	ORIGINAL ASSESS-MENT	PROPOSED QUADRISECTED INDEX	TRISECTED INDEX	FOUR INDIVIDUAL METRICS
DAVIS018.1CL	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	PASS	FAIL
DAVIS016.2CL	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	PASS	FAIL
DAVIS014.6CL	67F	SUPPORTING	PASS	PASS	FAIL
DAVIS011.6CL	67F	SUPPORTING	PASS	PASS	FAIL
JOCKE00.1WN	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	PASS	FAIL
MEADO00.4GE	67F	SUPPORTING	PASS	PASS	FAIL
MFORK0.4WN	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	PASS	FAIL
PISTO000.2BT	67F	IMPAIRED Pathogens Siltation	FAIL	FAIL	PASS
RICHL001.5GE	67F	SUPPORTING	PASS	PASS	FAIL
RICHL003.5GE	67F	IMPAIRED Nutrients Habitat	FAIL	FAIL	FAIL
RICHL004.2GE	67F	IMPAIRED Nutrients Habitat	FAIL	FAIL	FAIL
RUSSE000.3CL	67F	IMPAIRED Nutrients Pathogens Siltation	FAIL	FAIL	FAIL
ELLEJ000.1BT	67G	SUPPORTING	PASS	PASS	FAIL
ROCKCAST01	68A	SUPPORTING	PASS	PASS	FAIL
ROCKCAST02	68A	IMPAIRED Organic/DO Pathogens Thermal	FAIL	PASS	FAIL
FWATER02	68C	UNCLEAR	FAIL	PASS	FAIL
FWATER04	68C	IMPAIRED Organic/DO Siltation	FAIL	PASS	FAIL
LWFORK01	71E	SUPPORTING	PASS	PASS	FAIL

STATION	LEVEL IV SUB-REGION	ORIGINAL ASSESS-MENT	PROPOSED QUADRISECTED INDEX	TRISECTED INDEX	FOUR INDIVIDUAL METRICS
LWFORK02	71E	IMPAIRED Organic/DO Pathogens Siltation	FAIL	PASS	FAIL
JONES01	71F	SUPPORTING	PASS	PASS	FAIL
JONES02	71F	SUPPORTING	FAIL	PASS	FAIL
JONES02A	71F	IMPAIRED Organic/DO Siltation	FAIL	FAIL	FAIL
JONES03	71F	IMPAIRED Organic/DO Siltation	FAIL	PASS	FAIL
JONES04	71F	IMPAIRED Organic/DO Siltation	FAIL	PASS	FAIL
JONES06	71F	IMPAIRED Organic/DO Siltation	PASS	PASS	FAIL
JONES05	71F	IMPAIRED Organic/DO Siltation	FAIL	PASS	FAIL
BTURNB01	71F	SUPPORTING	FAIL	PASS	FAIL
BTURNB02	71F	SUPPORTING	PASS	PASS	FAIL
BTURNB03	71F	SUPPORTING	PASS	PASS	FAIL
TRACE01	71F	IMPAIRED Habitat	PASS	PASS	FAIL
TRACE02	71F	IMPAIRED Habitat	FAIL	PASS	FAIL
HURRI008.4HU	71F	SUPPORTING	PASS	PASS	FAIL
TOWN01	71G	IMPAIRED Organic/DO Pathogens	FAIL	PASS	FAIL
TOWN02	71G	IMPAIRED Organic/DO Pathogens	FAIL	PASS	FAIL
FLAT03	71G	SUPPORTING	PASS	PASS	PASS
MINELICK01	71G	IMPAIRED Organic/DO Pathogens	PASS	PASS	PASS
MINELICK02	71G	IMPAIRED Organic/DO Pathogens	FAIL	PASS	FAIL
INDIAN1T03	71H	SUPPORTING	PASS	PASS	PASS
WARTRACE01	71H	UNCLEAR	PASS	PASS	PASS
WARTRACE02	71H	UNCLEAR	PASS	PASS	FAIL
HICKMAN01	71H	SUPPORTING	FAIL	PASS	FAIL
HICKMAN02	71H	SUPPORTING	PASS	PASS	FAIL

STATION	LEVEL IV SUB-REGION	ORIGINAL ASSESS-MENT	PROPOSED QUADRISECTED INDEX	TRISECTED INDEX	FOUR INDIVIDUAL METRICS
BBIGBY02	71H	IMPAIRED Nutrients Pathogens	FAIL	FAIL	FAIL
BBIGBY03	71H	IMPAIRED Nutrients Pathogens	FAIL	PASS	FAIL
BBIGBY04	71H	IMPAIRED Nutrients Pathogens	PASS	PASS	FAIL
SPRING01	71I	SUPPORTING	PASS	PASS	FAIL
RLICK02	71I	IMPAIRED Habitat Organic/DO Siltation	PASS	PASS	FAIL
STEWA05.2RU	71I	SUPPORTING	PASS	PASS	FAIL
STEWA05.8RU	71I	IMPAIRED Habitat Nutrients Siltation	FAIL	FAIL	FAIL
HARPETH01	71I	SUPPORTING	PASS	PASS	PASS
HARPETH02	71I	IMPAIRED Habitat Organic/DO Siltation	PASS	PASS	PASS
CRIPP000.6RU	71I	SUPPORTING	PASS	PASS	PASS

8.1 Comparison of Proposed Biocriteria to Historic Assessments in Six Bioregions.

The proposed biocriteria were then compared to historic assessments in six bioregions from different areas of the state. All of the assessments had been conducted using single habitat semi-quantitative sampling techniques similar to those used to establish the reference database. The study sites represented various levels of impairment as well as sites that supported a healthy benthic community.

8.1.0 Comparison of Test Sites to Proposed Biocriterion in Bioregion 67fhi

Nine test stations in the Davis Creek subwatershed of the Powell River were used to test the sensitivity of the proposed biological criterion in bioregion 67fhi. Davis Creek is on the 1998 303(d) list for organic enrichment and sedimentation, primarily as a result of intense dairy operations. Some sites had significant loss of habitat. Six sites scored below the targeted index score of 32 indicating impairment of the benthic community (Table 5).

The three sites that met or exceeded the target index score had been assessed by state biologists as being the least impaired of those monitored during the stream survey. The assessment data for Davis Creek supports the biocriterion proposed for bioregion 67fhi as being responsive to a stressed macroinvertebrate community without being overly sensitive to slight impacts (Figure 48).

Table 5: Individual biometric and mulit-metric index scores for test sites in bioregion 67fhi

STATION	EPT	TR	%OC	%EPT	NCBI	% DOM	%CLING	INDEX SCORE
DAVIS024.1CL	1	15	4	1.3	7.20	76.8	10	18
DAVIS022.6CL	0	23	12	0	7.16	54.1	11	16
DAVIS020.5CL	6	20	0	19.3	4.76	21.0	36	24
DAVIS018.1CL	7	33	11	26.7	4.85	17.9	31	28
DAVIS016.2CL	6	37	23	36.6	5.48	15.4	35	30
DAVIS014.6CL	10	28	16	56	4.89	46.2	76	34
DAVIS011.6CL	9	24	2	65	3.93	32.7	76	38
CAWOO000.2CL	6	21	14	32.5	4.56	25.8	64	34
RUSSE000.3CL	4	34	57	3.1	5.95	22.2	14	20

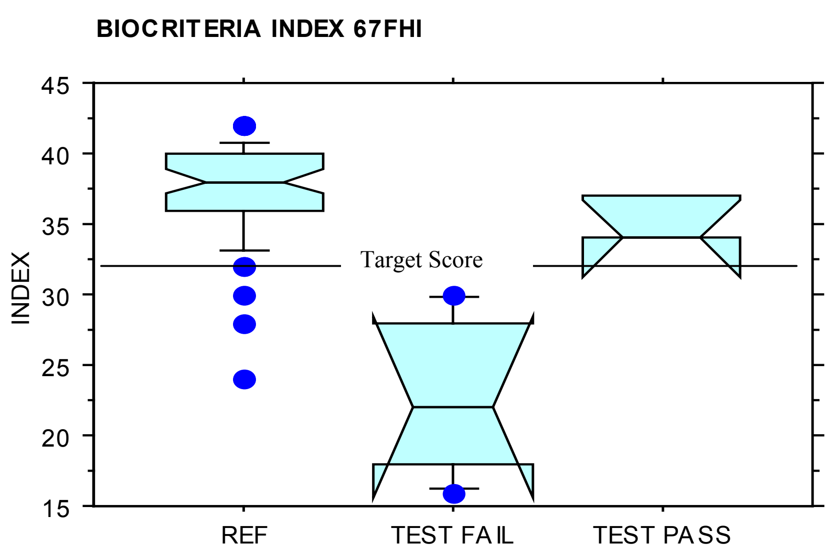


Figure 48: Comparison of multi-metric index scores between reference data in bioregion 67fhi and test sites in subregion 67f. Reference data represent multiple samples from 14 sites. Test data represent single samples from nine sites (6 fail, 3 pass).

8.1.1 Comparison of Test Sites to Proposed Biocriterion in Bioregion 68a.

The biological criterion proposed for bioregion 68a was compared to test data from a survey conducted by the Nashville Environmental Assistance Center (NEAC) on Rockcastle Creek to evaluate sensitivity of the index (Goodhue et al. 1997). The survey was conducted in October, 1995 and consisted of 2 sampling sites upstream and downstream of the Jamestown STP. A semi-quantitative riffle kick, directly comparable to the proposed biocriteria, was collected as part of the assessment. The original survey assessed the upstream area as supporting a healthy benthic community while the downstream site was partially supporting. The proposed criterion supported this finding with an upstream score of 36 exceeding the target score of 32 (Figure 49). The downstream site had a score of 26, falling below the target score of 32.

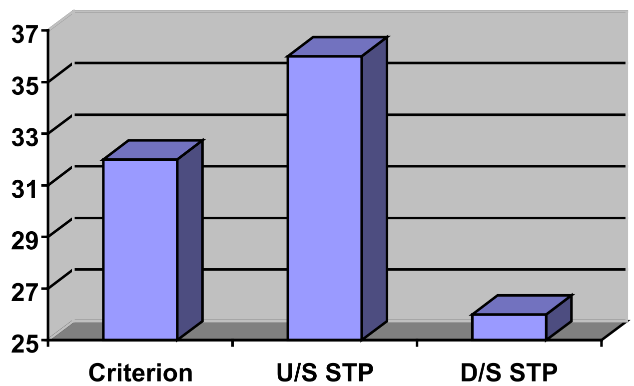


Figure 49: Comparison of multi-metric index scores at two test sites, upstream and downstream of an STP, to proposed biocriterion in bioregion 68a.

8.1.2 Comparison of Test Sites to Proposed Biocriterion in Bioregion 68c.

The proposed criterion in bioregion 68c was compared to two sites assessed by WPC on the Falling Water River (Goodhue, 1995). The sites were located upstream and downstream of a sewage treatment plant. Semi-quantitative riffle kicks were collected as part of the assessment. The site downstream of the STP was assessed as non-impaired compared to the upstream site. However, the results were inconclusive due to the possibility of the upstream site being affected by bypassing which occurs near the headwaters.

Use of a regional reference index would help clarify these types of assessments where the quality of the upstream site in uncertain. In this case, the upstream site exceeded the fall criteria of 27 with a score of 28 (Figure 50). The downstream site with a score of 26 would be considered impaired.

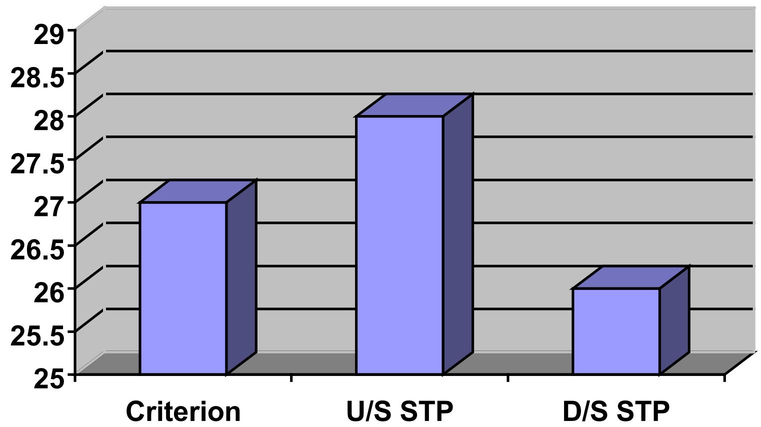


Figure 50: Comparison of multi-metric index scores at two test sites, upstream and downstream of an STP, to proposed biocriterion in bioregion 68c.

8.1.3 <u>Comparison of Test Sites to Proposed Biocriterion on Bioregion 71e.</u>

The proposed biological criterion index for bioregion 71e was applied to two previously assessed sites on Little West Fork Creek. The sites were upstream and downstream of the Fort Campbell Sewage Treatment Plant and had been assessed using a semi-quantitative riffle kick in conjunction with qualitative habitat samples. The original survey assessed the downstream portion of the stream as moderately impaired (Smith, 1996). When the proposed biocriteria index was applied to these sites, the same results were achieved. The upstream site scored 40, which is well above the target index score. The downstream site scored 30, falling below the target index score of 32 (Figure 51). The fact that the upstream site was well above the target index scores reinforces the attainability of the proposed biocriteria.

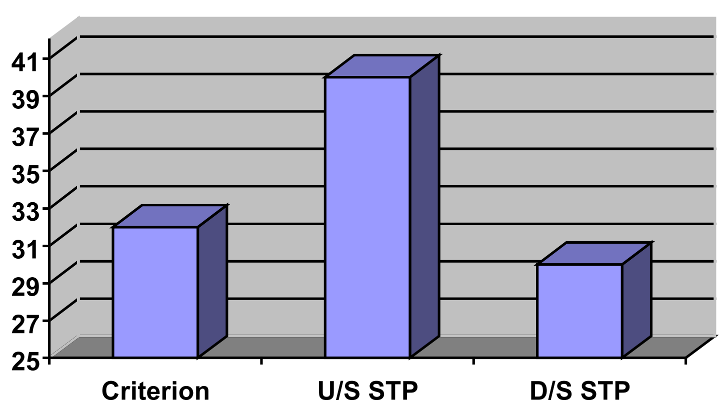


Figure 51: Comparison of multi-metric index scores at two test sites, upstream and downstream of an STP, to proposed biocriterion in bioregion 71i.

8.1.4 Comparison of Test Sites to Proposed Biocriterion in Bioregion 71fgh

Test data from 26 sites in subregions 71f, 71g and 71h were compared to the proposed biological criterion in the bioregion that includes all three subregions (Figure 52). The original assessments were conducted by three separate investigators over a 4-year period. (Gillis, 1993, Smith, 1994, Goodhue, 1996, Isenhour, 1994, Gillis, 1994, Goodhue, 1996, Smith, 1995). Semi-quantitative kick samples were used in conjunction with qualitative habitat samples to assess the sites. Fifty percent of the sites were originally assessed as being partially or non-supporting and fifty percent were rated as fully supporting by the original investigators. Thirteen sites were in ecological subregion 71f, five sites were in 71g and eight sites were in 71h. Index scores agreed with the original assessment 77 percent of the time (Table 4).

In three cases, the original assessment rated the stream as unimpaired while the index indicated impairment. In all three cases, the investigator was uncertain about the impairment rating. At three other sites, the original assessment rated the stream as impaired while the index indicated no impairment.

This comparison indicates that the index is responsive to moderate or heavy impairment but perhaps not to very slight impairment. Since disagreements in assessment were spread over all three regions, it also indicates that the grouping of these regions to create an index is appropriate.

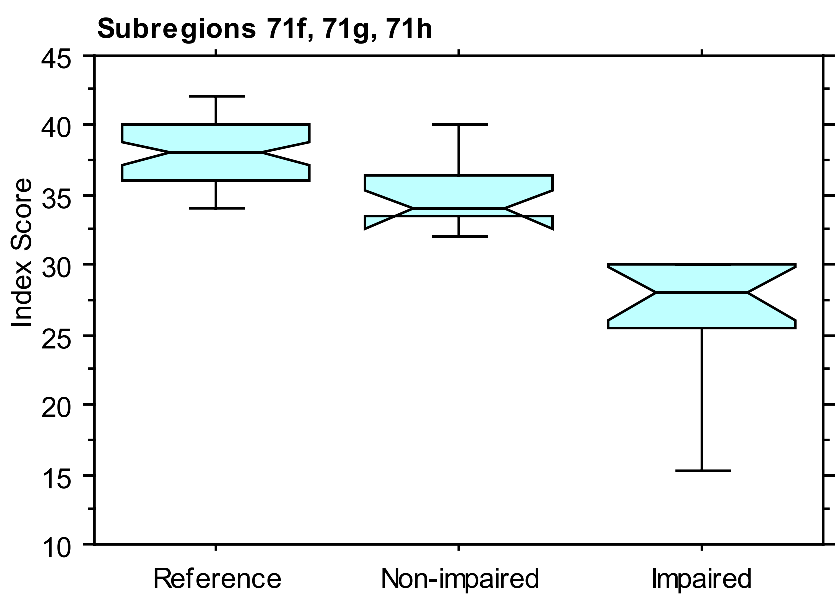


Figure 52: Comparison of reference multi-metric index scores to 26 test sites in the bioregion that includes ecological subregions 71f, 71g, and 71h. The reference data range includes multiple samples from 11 sites. The non-impaired sites are 13 that passed the proposed biocriterion. The impaired sites include 13 that failed to meet the proposed biocriterion.

8.1.5 Comparison of Test Sites to Proposed Biocriterion in Bioregion 71i.

Seven previously assessed sites in bioregion 71i were compared to the proposed reference criteria to measure sensitivity of the index. The seven sites represent five streams assessed over a 3-year period by three separate investigators (Smith, 1995, Arnwine and Augustin, 1999, Gillis, 1992). Three of these sites were collected using the semi-quantitative bank jab (SQBANK) and four were sampled using the semi-quantitative riffle kick (SQKICK) method so the proposed biocriteria for both sample types were tested. All sites were assessed during the late summer/fall sampling period. During the original assessments, two sites were rated as having moderate impairment and one was rated as having slight impairment based on the macroinvertebrate population. None of these sites failed to meet the proposed criteria. One site, originally assessed as non-impaired compared to upstream reference, failed to meet the proposed criteria.

The difficulty in making consistent assessments in this region illustrates the need for numeric criteria based on regional reference data. Since all assessments were conducted in the low-flow period, it also argues the case that spring assessments in this region may be more meaningful.

8.2 Comparison of Probabilistic Monitoring Data to Proposed Biocriterion in Bioregion 71i.

A probabilistic monitoring project was conducted during 2000 in the Inner Nashville Basin (TDEC 2000). Fifty streams were randomly selected. Macroinvertebrates were sampled using the same techniques used to establish the reference database at each randomly selected test site for two seasons (spring and fall). Four of the streams monitored as part of the probabilistic monitoring study proved to be as good or better than the established reference streams in this region. Data from these four streams were included in criteria determination.

The majority of the streams evaluated in the probabilistic monitoring project had observable impacts from urban development, habitat destruction, riparian loss and/or livestock access. Sixty-four percent of the randomly selected sites failed to meet the proposed criteria in the spring. All of the reference streams in this region had some level of impact, so criteria should be attainable for most streams in this region with appropriate management practices.

Many streams in this region are dry in the late summer or fall. Forty-two percent of the randomly selected streams were dry by October 2000. The two established reference sites in this region were also dry. Because of naturally stressed conditions, the target index score is set at a lower level in the fall season. Of the 29 streams that had flowing water, 62% passed the fall criteria (Table 6).

Eleven of the 29 streams with year round-flow changed assessment between the spring and fall season. Eight streams that had failed spring criteria passed in the fall when expectations were lowered. Fall criteria were based on reference data from streams that have greatly reduced fall flow and a naturally less diverse benthic community. The eight streams that failed to meet spring criteria but passed in the fall had good flow year-round and should be able to support healthy benthic populations both seasons.

Three streams that had passed in the spring, failed the proposed fall criteria. These three streams had extremely reduced flow. Riffle areas were dry, changing the sampling method from riffle kicks in the spring to rooted bank jabs in the fall. Figure 53 illustrates the distribution of index scores between reference sites and test sites by season and sampling method.

It is recommended that streams in this region be assessed only in the spring/early summer period (February – June). This would insure streams had flow and supported the most diverse benthic community. Assessments would also be more comparable to reference streams with extremely reduced flow in the dry season. Streams assessed in late summer or fall may be measuring natural stress or the amount of water available instead of pollution.

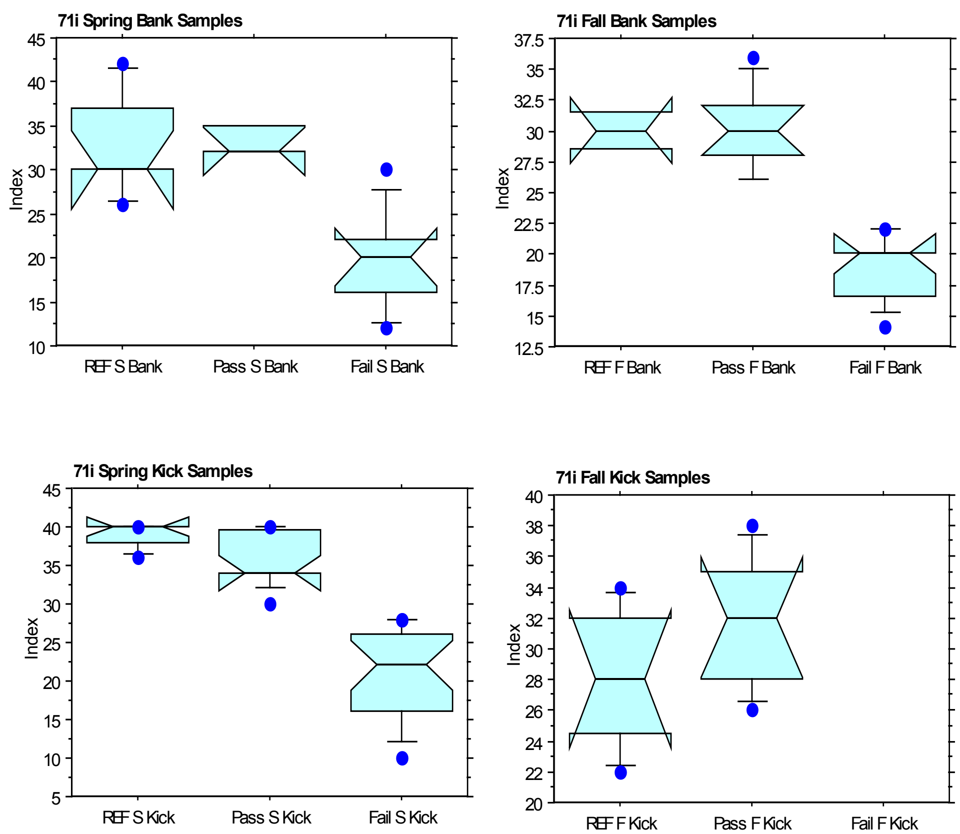


Figure 53: Comparison of multi-metric index scores at 50 probabilistic monitoring sites to reference data in bioregion 71i. Plots are split by season and sample type. Reference data represent multiple samples at seven sites for kick samples and two sites for bank samples. Pass represents sites that had index scores above the proposed biocriteria while Fail designates sites whose index scores fell below the proposed biocriteria index score.

Table 6: Assessments based on proposed criteria at streams with year round flow in bioregion 71i (Inner Nashville Basin)

	SPRING		FALL	
	PASS/FAIL	METHOD	PASS/FAIL	METHOD
BRADL003.8RU	PASS	BANK	PASS	BANK
BARTO017.6WS	FAIL	KICK	FAIL	BANK
BROCK006.0ML	FAIL	KICK	PASS	KICK
BUSH002.2RU	PASS	KICK	PASS	KICK
CEDAR004.6WS	PASS	KICK	PASS	KICK
CEDAR011.8WS	PASS	KICK	PASS	KICK
CHRIS000.7RU	FAIL	BANK	PASS	BANK
CRIPPOO3.0RU	FAIL	BANK	PASS	BANK
EFSTO026.6RU	PASS	BANK	PASS	BANK
FALL003.0BE	FAIL	KICK	PASS	BANK
FALL003.6RU	PASS	KICK	PASS	KICK
FALL018.8WS	PASS	KICK	FAIL	BANK
FLORI002.4WS	PASS	KICK	PASS	FAIL
HARPE076.0WI	PASS	KICK	PASS	KICK
LITTL001.8WS	PASS	KICK	FAIL	BANK
LYTLE000.6RU	FAIL	KICK	PASS	KICK
MCKNI001.2RU	FAIL	BANK	FAIL	BANK
MILL012.4DA	FAIL	KICK	FAIL	KICK
MILL021.2DA	FAIL	KICK	FAIL	KICK
OVERA009.4RU	PASS	KICK	PASS	KICK
SPENC005.0WS	FAIL	KICK	PASS	BANK
SPRIN004.4WS	PASS	KICK	PASS	KICK
SPRIN016.0WS	PASS	KICK	FAIL	BANK
SPRIN027.0WS	PASS	BANK	FAIL	BANK
STEWA018.2RU	FAIL	BANK	FAIL	BANK
SUGGS007.7WS	FAIL	BANK	FAIL	BANK
WFSTO013.6RU	FAIL	BANK	FAIL	BANK
WFSTO023.2RU	FAIL	KICK	PASS	KICK
WILSO0005.2BE	FAIL	KICK	PASS	KICK

9. BIOCRITERIA RECOMMENDATIONS

Separate biocriteria to evaluate the integrity of the benthic macroinvertebrate community are proposed for 15 grouped subregions (bioregions) based on regional reference data. In seven regions, separate criteria were developed dependent on season. Two criteria based on sample type were determined in one subregion. The proposed index criterion for each bioregion is based on the same seven biometrics except in bioregion 73 where only five metrics proved viable. Different metric scoring ranges were calculated for each bioregion. Target index scores (biocriteria) are based on regional and seasonal expectations for each metric.

The biocriteria indices should only be applied to streams that are comparable to those in the reference stream database for each bioregion (ecological subregion or similar group of subregions). To be comparable, the drainage upstream of a study site must be entirely or mostly (80%) within a bioregion. The stream should be similar in size to those used in the study (varies by bioregion). The proposed biocriteria would not be appropriate for use in lakes, reservoirs or wetlands. The biocriteria can only be used to assess non-wadeable streams or rivers in bioregions 73a and 65abei-74b where non-wadeable streams were included in the reference database.

These criteria are based on single habitat, semi-quantitative macroinvertebrate samples. The same sample method and habitat type must be collected at study sites for comparison to criteria. All criteria were developed using a 200-organism subsample identified to the genus level. Subsamples that are larger or smaller, as well as samples identified to different taxonomic levels, such as family or species, would not be comparable.

Seasonal differences were significant in some bioregions. Criteria were adjusted for seasonality in these regions. The appropriate index should be used based on the month sampled within these regions.

Regional interpretations of the narrative criteria should be used primarily for water quality assessment purposes.

10. CONCLUSIONS

Evaluation of the macroinvertebrate reference data supports the establishment of regional biocriteria. Benthic macroinvertebrate populations proved distinct in 15 bioregions throughout the state. For this study, a bioregion was defined as an ecological subregion or group of subregions that supported similar macroinvertebrate communities for assessment purposes.

Seven biometrics representing four different categories were selected as being the most responsive to changes in the benthic community structure. Each selected metric was sensitive to a different aspect of the benthos and/or to a different type of pollution or physical disturbance. The seven metrics were combined into a single index to simplify assessments. The criteria based on this index proved responsive to moderate and high levels of impairment. The same set of metrics will be used statewide except in bioregion 73a (Northern Mississippi Alluvial Plain) where only five of the metrics were responsive. Metric expectations were adjusted by bioregion to develop regional indices. Expected ranges were calculated by quadrisecting reference data at the 90^{th} or 10^{th} percentile depending on the direction of response for the metric. Multivariate analysis was used to separate biocriteria by region and/or season where appropriate.

Comparison of randomly selected streams in bioregion 71i (Inner Nashville Basin) indicated the proposed biocriteria are responsive to moderate to high levels of impact. This study demonstrated slightly impaired streams would pass biocriteria. Since all reference sites in this subregion receive some level of nonpoint source pollution, the proposed criteria should be attainable through better management practices at the majority of streams in this region.

The proposed biocriteria were also compared to historic assessments at 60 sites in six bioregions that reflected different areas of the state. The study sites represented various levels of impairment as well as sites that supported a healthy benthic community. The criteria agreed with original assessments for the majority of sites. When criteria disagreed with the previous assessment, the criteria generally rated the stream as less impaired.

Criteria were developed based primarily on reference data collected during the 3-year ecoregion monitoring project. The original reference sites, as well as newly discovered reference quality streams are now being monitored in five-year cycles in conjunction with watershed monitoring. Over time, adjustments to biocriteria may need to be implemented as additional data are added to the database. Biocriteria in some subregions may also need reevaluation if they prove overly sensitive or non-discriminatory when compared to test sites collected in the same regions.

The use of regional biocriteria based on reference data will help standardize biological assessments. It will also help clarify interpretations of stream health in questionable cases. As an additional benefit, standardized biocriteria based on regional reference data will decrease the need for reference or upstream monitoring during water quality investigations, thus reducing monitoring time and costs, allowing more time for assessing stream reaches where no data is available and for monitoring problem sites.

11. BIOCRITERIA IMPLEMENTATION QUESTIONS AND ANSWERS

What has the Division recommended and what is the basis for the selected approach?

The Division has recommended that a set of seven biological metrics be combined to form a stream biological integrity index. These benthic macroinvertebrate metrics, selected based on their ability to measure different critical aspects of stream ecology, can be used to compare the biological integrity of a stream to the reference condition. The reference condition has been established based on data collected at reference streams throughout Tennessee.

How will biocriteria be used and will they replace the existing narrative biological integrity criteria?

The Division will recommend that these biological integrity goals be formalized into Tennessee's General Water Quality Criteria (Chapter 1200-4-3). The proposed biocriteria will supplement, rather than replace, the existing narrative criteria.

Biocriteria, as developed by Tennessee, reflect regional differences in biological communities and will help make the application of Tennessee's existing narrative criteria more accurate and appropriate. In order to be considered to meet the biological integrity goal, a stream would generally have to measure within 75 percent of the reference condition. Criteria at other levels and using other metrics were considered, but were rejected when they appeared overly conservative, or not conservative enough, during field-testing.

Will the proposed set of biocriteria apply to all waterbodies in Tennessee?

No. The biocriteria developed by the Division apply only to certain streams. The watershed drainage upstream of the study site must be at least 80 percent within a bioregion (ecological subregion or similar group of subregions). The criteria will not be applied to lakes, wetlands, or large rivers. Additionally, in order for the biocriteria to apply, the stream will have to be studied in a specific manner. For lakes, wetlands, and large rivers where the biocriteria do not apply, the existing narrative criteria will be applicable.

How will I know which bioregion I am in and whether or not the biocriteria apply to my stream?

A poster of the ecoregions of Tennessee is available at no charge from the Division. The Department's homepage contains ecoregion maps as well. Additionally, EPA developed GIS coverage of the subecoregion boundaries that can also be provided to groups or individuals with those capabilities.

A good rule of thumb is to check the aerial coverage of the biocriteria where you are sited. (Biocriteria can be based on individual subregions or combinations of subregions called bioregions.) If your stream is wadeable and the upstream portion of the watershed is wholly contained (or at least 80%) within the bioregion within which the criterion is based, the biocriterion probably applies to your stream. If you are in doubt, check with the Division.

Is the reference condition an attainable and therefore, reasonable, goal for Tennessee streams?

Many people presume that reference streams represent pristine conditions, but that is not necessarily accurate. In each region, reference streams had to meet two tests. They had to be both representative and least-impaired.

In most regions of Tennessee, streams that could be considered unimpaired were unavailable. Good reference streams were particularly difficult to locate in west Tennessee, the Inner Nashville Basin of middle Tennessee, and the Ridge and Valley ecoregion of east Tennessee. In many areas, we had to accept reference streams that were substantially altered simply because they were the best available in that region.

Because the reference streams are not pristine and in most cases have been altered by development, agriculture, or other land uses, we feel strongly that the reference condition is attainable with proper pollution controls.

How many other states currently have numeric biocriteria?

Many states have numeric quantitative biological thresholds that could serve as biocriteria. Three states (Ohio, Florida and Vermont) already have specific numeric biocriteria in place. Kentucky uses numeric criteria for outstanding waters and is developing numeric criteria for all waters. Maine and Oregon will have numeric biocriteria in place within the next year. Maryland is developing numeric criteria that are expected to be in place within the next 2 years. North Carolina has narrative biocriteria that refer to specific numbers in their standard operating procedure. Many other states including (but not limited to) Alabama, Mississippi, South Carolina and Georgia, are at some stage in numeric biocriteria development.

Has the Division's proposal been peer reviewed?

Yes. In addition to the normal in-house review, regional and headquarter EPA staff, plus our counterparts in neighboring states reviewed this document. Several scientists, selected from a pool of experts noted for their expertise in the area of biological criteria development, also reviewed the document. Their comments were incorporated into the document.

Copies of the Division's responses to the formal comments can be obtained by those wishing to further their understanding of these issues.

Will biocriteria be revised in future triennial reviews?

Yes, if appropriate. We are continuing to monitor our existing reference streams in conjunction with the watershed cycles. Additionally, several adjacent states are in the process of selecting reference streams. For the subecoregions we have in common, if methodologies are similar, it will be possible to share our data with other states and vice versa. These data will be added to the existing database and will help refine the reference condition. The biocriteria can be adjusted, as needed, in future triennial reviews.

However, we do not believe the revisions will be substantial. Additionally, there is no basis for a presumption that any revisions would be in the direction of making the biocriteria more stringent.

Will biocriteria be applied as permit limits?

No. The biocriterion forms the goal for the stream, not for the quality of effluent discharges. However, permit holders may be given a permit requirement to monitor the biological quality in their receiving stream. Streams that do not meet the biocriteria goal will be considered appropriate for inclusion on the 303(d) List.

Facilities that do not perform monitoring in the specified manner or frequency would be considered in violation of their permit conditions and subject to enforcement.

My facility was given a requirement to perform biological monitoring on our receiving stream. Why does the Division stipulate how this monitoring must be done?

In order for biological data to be comparable to the reference database, samples must be collected and processed in the exact same fashion. That is why permits with biological monitoring requirements will stipulate a sampling method and the Division will insist that it be followed.

The proposed biocriteria are based on a series of detailed biological surveys performed at each of the reference streams. These Semi-Quantitative Single Habitat Assessments, as they are called, require that benthic invertebrates be identified down to genera. Thus, laboratory bench-time is required as many genera cannot be accurately and positively identified in the field.

One way we minimized costs was to appropriately subsample. This method is based on EPA guidance documents and has been approved for use in evaluating biological integrity. Alternate subsample protocols or sample sizes may not be comparable.

Since the biocriteria are based on the results of Semi-Quantitative Single Habitat Assessments, does that mean that the Division will only be performing that type of biological survey in the future?

The less strenuous biorecon surveys will still have an important place in our monitoring strategy. Biorecons can often be completed in the field, thus reducing the need for subsequent sample analysis.

Biorecons will be used primarily for screening. In cases where a stream is very good or very bad, a biorecon can be used to assess streams in a more cost and time effective manner. For streams that are borderline in quality, or where important regulatory decisions must be made, the more rigorous survey may be necessary.

What will happen if the Water Quality Control Board decides to stick with the existing narrative biological integrity criteria rather than promulgate the Division's recommendation?

The Division's proposal to formalize regional interpretations of the existing narrative biological integrity criteria is simply a science-based recommendation. We consider it in the interests of Tennesseans to explore these issues in a public forum, like the one provided by the rulemaking process.

It is the responsibility of the Board to consider the advice they are given, not only from the Division, but also from other informed sources.

If this recommendation is not established in the water quality standards - and nothing else is put in its place - then we would likely revert back to the original narrative criteria that gives the Division a large amount of flexibility on how to interpret the existing language. In fact, nothing would preclude the Division from using our original recommendation less formally.

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APPENDIX A

LEVEL IV ECOREGIONS IN TENNESSEE

Adapted from Ecoregions of Tennessee (Griffith et al, 1997)

65a The **Blackland Prairie,** extending north from Mississippi, is a flat to undulating lowland region covering only a small portion of McNairy County, Tennessee. Although there is some of the Cretaceous-age chalk, marl, and calcareous clay that characterizes the region in Mississippi and Alabama, the northern extent of the Blackland Prairie in Tennessee is not distinct. To the south, the natural vegetation had dominant trees of sweetgum, post oak, and red cedar, along with patches of bluestem prairie. Today, the area is mostly in cropland and pasture, with small patches of mixed hardwoods.

65b The **Flatwoods/Alluvial Prairie Margins** extend north from Mississippi, but the distinctiveness of this narrow ecoregion belt fades quickly from Ripley, Mississippi north into Tennessee. In Mississippi and Alabama, this is a transition region between the Blackland Prairie and the more forested plains and hills. Some areas are heavily forested, but the prairie and alluvial areas now have significant amounts of cropland and pasture. In Tennessee, the small region stands out as lower, less hilly agricultural land compared to the forested Southeastern Plains and Hills (65e) that surround it.

65e The **Southeastern Plains and Hills** contain several north-south trending bands of sand and clay formations. Tertiary-age sand, clay, and lignite are to the west, and Cretaceous-age fine sand, fossiliferous micaceous sand, and silty clays are to the east. With elevations reaching over 650 feet, and more rolling topography and more relief than the Loess Plains (74b) to the west, streams have increased gradient, generally sandy substrates, and distinctive faunal characteristics for west Tennessee. The natural vegetation type is oak-hickory forest, grading into oak-hickory-pine to the south.

65i **The Fall Line Hills** ecoregion, comprising the Tennessee or Tombigbee Hills in Mississippi and the Fall Line Hills in Alabama, is composed primarily of Cretaceous-age coastal plain sandy sediments. The sand and chert gravel surficial materials are covered by sandy loam topsoils. It is mostly forested terrain of oak-hickory-pine on open hills with 100-200 feet of relief. Elevations in the small Tennessee portion, roughly between Chambers Creek and Pickwick Lake in Hardin County, are 450-685 feet.

65j **The Transition Hills** have the highest elevations in Ecoregion 65, and contain characteristics of both the Southeastern Plains (65e) and the Interior Plateau (71) ecoregions. Many streams of this transition area have cut down into the Mississippian, Devonian, and Silurian-age rocks and may look similar to those of the Interior Plateau (71). Cretaceous-age coastal plain deposits of silt, sand, clay, and gravel overlie the older limestone, shale, and chert. It is a mostly forested region of oak-hickory-pine, and has pine plantation activities associated with pulp and paper operations.

66d **The Southern Igneous Ridges and Mountains** occur in Tennessee's northeastern Blue Ridge near the North Carolina border, primarily on Precambrian-age igneous, gneiss, schist, and metavolcanics, covered by well-drained, acidic brown loamy soils. Elevations of this rough, dissected region range from 2000-6200 feet, with Roan Mountain reaching 6286 feet. Although there are a few small areas of pasture and apple orchards, the region is mostly forested. Appalachian oak and northern hardwoods forests predominate.

66e	The **Southern Sedimentary Ridges** in Tennessee include some of the westernmost foothill areas of the Blue Ridge Mountains ecoregion, such as Bean, Starr, Chilhowee, English, Stone, Bald, and Iron Mountain. Slopes are steep with elevations of 1000-4500 feet. The rocks are primarily Cambrian-age sedimentary (shale, sandstone, siltstone, quartzite, conglomerate), although some lower stream reaches occur on limestone. Soils are predominantly friable loams and fine sandy loams with variable amounts of sandstone rock fragments. Natural vegetation is mostly mixed oak and oak-pine forests.

66f	**Limestone Valleys and Coves** are small but distinct lowland areas of the Blue Ridge, with elevations mostly between 1500 and 2500 feet. About 450 million years ago, older Blue Ridge rocks to the east were forced up and over younger rocks to the west. In places, the Precambrian rocks have eroded through to Cambrian or Ordovician-age limestones, as seen especially in isolated, deep cove areas that are surrounded by steep mountains. The main areas of limestone include the Mountain City lowland area and Shady Valley in the north; and Wear Cove, Tuckaleechee Cove, and Cades Cove of the Great Smoky Mountains in the south. Hay and pasture, with some tobacco patches on small farms, are typical land uses.

66g	The **Southern Metasedimentary Mountains** are steep, dissected, biologically diverse mountains that include Clingmans Dome (6643 feet), the highest point in Tennessee. The Precambrian-age metamorphic and sedimentary geologic materials are generally older and more metamorphosed than the Southern Sedimentary Ridges (66e) to the west and north. The Appalachian oak forests and, at higher elevation, the northern hardwoods include a variety of oaks and pines, as well as silverbell, hemlock, yellow poplar, basswood, buckeye, yellow birch, and beech. The native spruce-fir forest, found generally above 5500 feet, has been affected greatly over the past twenty-five years by the great woolly aphid. The Copper Basin, in the southeast corner of Tennessee, was the site of copper mining and smelting from the 1850's to 1987, and once left more than fifty square miles of eroded bare earth. Distinct subregion status for the Copper Basin has been proposed as 66j (Broad Basins).

67f	The **Southern Limestone/Dolomite Valleys and Low Rolling Hills** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the soils vary in their productivity. Landcover includes intensive agriculture, urban and industrial uses, as well as areas of thick forest. White oak forest, bottomland oak forest, and sycamore-ash-elm riparian forests are the common forest types. Grassland barrens intermixed with cedar-pine glades also occur here.

67g	The **Southern Shale Valleys** consist of lowlands, rolling valleys, slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn, tobacco, and garden crops are grown on the foot slopes and bottom land.

67h The **Southern Sandstone Ridges** ecoregion encompasses the major sandstone ridges, but these ridges also have areas of shale and siltstone. The steep, forested ridges have narrow crests with soils that are typically stony, sandy, and of low fertility. The chemistry of streams flowing down the ridges can vary greatly depending on the geological material. The higher elevation ridges are in the north, including Wallen Ridge, Powell Mountain, Clinch Mountain and Bays Mountain. White Oak Mountain in the south has some sandstone on the west side, but abundant shale and limestone as well. Grindstone Mountain, capped by the Gizzard Group sandstone, is the only remnant of Pennsylvanian-age strata in the ridge and valley of Tennessee.

67i The **Southern Dissected Ridges and Knobs** contain more crenulated, broken, or hummocky ridges, compared to the smoother, more sharply pointed sandstone geologic materials. The ridges on the east side of Tennessee's Ridge and Valley tend to be associated with the Ordovician-age Sevier shale, Athens shale, and Holston and Lenoir limestones. These can include calcareous shale, limestone, siltstone, sandstone, and conglomerate. In the central and western part of Ecoregion 67i, the shale ridges are associated with the Cambrian-age Rome Formation: shale and siltstone with beds of sandstone. Chestnut oak forests and pine forests are typical for the higher elevations of the ridges, with areas of white oak, mixed mesophytic forest, and tulip poplar on the lower slopes, knobs, and draws.

68a The **Cumberland Plateau** consists of tablelands and open low mountains about 1000 feet higher than the Eastern Highland Rim (71g) to the west, and receive slightly more precipitation with cooler annual temperatures than the surrounding lower-elevation ecoregions. The plateau surface is less dissected with lower relief compared to the Cumberland Mountains (69d) or the Plateau Escarpment (68c). Elevations are generally 1200-2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvanian-age conglomerate, sandstone, siltstone, and shale are covered by well-drained, acid soils of low fertility. The region is forested with some agriculture and coal mining activities.

68b The **Sequatchie Valley** is structurally associated with an anticline, where erosion of broken rock to the south of the Crab Orchard Mountains scooped out the linear valley. The open, rolling, valley floor, 600-1000 feet in elevation, is generally 1000 feet below the top of the Cumberland Plateau. A low, central, cherty ridge separates the west and east valleys of Mississippian to Ordovician-age limestones, dolomites, and shales. Similar to parts of the Ridge and Valley (67), this is an agriculturally productive region, with areas of pasture, hay, soybeans, small grain, corn, and tobacco.

68c The **Plateau Escarpment** is characterized by steep, forested slopes and high velocity, high gradient streams. Local relief is often 1000 feet or more. The geologic strata include Mississippian-age limestone, sandstone, shale, and siltstone, and Pennsylvanian-age shale, siltstone, sandstone, and conglomerate. Streams have cut down into the limestone, but the gorge talus slopes are composed of colluvium with huge angular, slabby blocks of sandstone. Vegetation community types in the ravines and gorges include mixed oak and chestnut oak on the upper slopes, mesic forests on the middle and lower slopes (beech-tulip poplar, sugar maple-basswood-ash-buckeye), with hemlock along rocky streamsides and river birch along floodplain terraces.

69d The **Cumberland Mountains**, in contrast to the sandstone-dominated Cumberland Plateau (68a) to the west and southwest, are more highly dissected, with narrow-crested steep slopes, and younger Pennsylvanian-age shales, sandstones, siltstones, and coal. Narrow, winding valleys separate the mountain ridges, and relief is often 2000 feet. Cross Mountain, west of Lake City, reaches 3534 feet in elevation. Soils are generally well-drained, loamy, and acidic, with low fertility. The natural vegetation is a mixed mesophytic forest, although composition and abundance vary greatly depending on aspect, slope position, and degree of shading from adjacent landmasses. Large tracts of land are owned by lumber and coal companies, and there are many areas of stripmining.

71e The **Western Pennyroyal Karst** is a flatter area of irregular plains, with fewer perennial streams compared to the open hills of the Western Highland Rim (71f). Small sinkholes and depressions are common. The productive soils of this highly agricultural area formed mostly from a thin loess mantle over Mississippian-age limestones. Most of the region is cultivated or in pasture. Tobacco and livestock are the principal agricultural products, with some corn, soybeans, and small grains. The natural vegetation consists of oak-hickory forest with mosaics of bluestem prairie. The barrens of Kentucky that extended south into Stewart, Montgomery, and Robertson counties, were once some of the largest grasslands in Tennessee.

71f The **Western Highland Rim** is characterized by dissected, rolling terrain of open hills, with elevations of 400-1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty and acidic with low to moderate fertility. Streams are relatively clear with a moderate gradient. Substrates are coarse chert, gravel and sand with areas of bedrock. The native oak-hickory forests were removed over broad areas in the mid-to late 1800's in conjunction with the iron-ore related mining and smelting of the mineral limonite, however today the region is again heavily forested. Some agriculture occurs on the flatter interfluves and in the stream and river valleys. The predominant land uses are hay, pasture, and cattle with some cultivation of corn and tobacco.

71g The **Eastern Highland Rim** has more level terrain than the Western Highland Rim (71f), with landforms characterized as tablelands of moderate relief and irregular plains. Mississippian-age limestone, chert, shale and dolomite predominate. Karst terrain sinkholes and depressions are especially noticeable between Sparta and McMinnville. Numerous springs and spring-associated fish fauna typify the region. Natural vegetation is transitional between the oak-hickory forests to the west and the mixed mesophytic forests of the Appalachian ecoregions (68, 69) to the east. Bottomland hardwoods forests were once abundant in some areas, although much of the original bottomland forest has been inundated by several large impoundments. Barrens and former prairie areas are now primarily oak thickets, pasture or cropland.

71h The **Outer Nashville Basin** is a more heterogeneous region than the Inner Nashville Basin (71i), with rolling and hilly topography with slightly higher elevations. The region encompasses most of the outer areas of the generally non-cherty Ordovician limestone bedrock. The higher hills and knobs are capped by the more cherty Mississippian-age formation, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forest with pasture and cropland are the dominant land covers. The region has areas of intense urban development with the city of Nashville occupying the northwest region. Streams are low to moderate gradient, with productive, nutrient-rich waters, resulting in algae, rooted vegetation, and occasionally high densities of fish. The Nashville Basin has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

71i The **Inner Nashville Basin** is less hilly and lower than the Outer Nashville Basin (71h). Outcrops of the Ordovician-age limestone are common. The generally shallow soils are redder and lower in phosphorus than those of the outer basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the inner basin are a maple-oak-hickory-ash-association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest cedar glades vegetation type with many endemic species, are located primarily on the limestones of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species. Urban, suburban, and industrial land use in the region is increasing.

73a The **Northern Mississippi Alluvial Plain** within Tennessee is a relatively flat region of the Quaternary alluvial deposits of sand, silt, clay, and gravel. It is bounded distinctly on the east by the Bluff Hills (74a), and on the west by the Mississippi River. Average elevations are 200-300 feet with little relief. Most of the region is in cropland, with isolated areas of deciduous forest. Soybeans, cotton, corn, sorghum, and vegetables are the main crops. The natural vegetation consists of Southern floodplain forest (oak, tupelo, bald cypress). The two main distinctions in the Tennessee portion of the ecoregion are between areas of loamy, silty, and sandy soils with better drainage, and areas of more clayey soils of poor drainage that may contain wooded swampland and oxbow lakes. Waterfowl, raptors, and migratory songbirds are relatively abundant in the region. A proposal has been made to change the name of this subregion to the Mississippi River Meander Belt. A second subregion in Dyer County, Tennessee, 73d-Pleisotocene Valley Trains, has also been proposed.

74a The **Bluff Hills** consist of sand, clay, silt, and lignite, and are capped by loess greater than 60 feet deep. The disjunct region in Tennessee encompasses those thick loess areas that are generally the steepest, most dissected, and forested. The carved loess has a mosaic of microenvironments, including dry slopes and ridges, moist slopes, ravines, bottomland areas, and small cypress swamps. While oak-hickory is the general forest type, some of the undisturbed bluff vegetation is rich in mesophytes, such as beech and sugar maple, with similarities to hardwood forests of eastern Tennessee. Smaller streams of the Bluff Hills have localized reaches of increased gradient and small areas of gravel substrate that create aquatic habitats that are distinct from those of the Loess Plains (74b) to the east.

74b The **Loess Plains** are gently rolling, irregular plains, 250-500 feet in elevation, with loess up to 50 feet thick. The region is a productive agricultural area of soybeans cotton, corn, milo, and sorghum crops, along with livestock and poultry. Soil erosion can be a problem on the steeper, upland Alfisol soils. Bottom soils are mostly silty Entisols. Oak-hickory and southern floodplain forests are the natural vegetation types, although most of the forest cover has been removed for cropland. Some less-disturbed bottomland forest and cypress-gum swamp habitats still remain. Several large river systems with wide floodplains; the Obion, Forked Deer, Hatchie, Loosahatchie, and Wolf, cross the region. Streams are low-gradient and murky with silt and sand bottoms. Most of the streams have been channelized.

APPENDIX B

ECOREGIONAL REFERENCE SITES USED IN BIOCRITERIA DETERMINATION

TENNESSEE ECOREGION REFERENCE SITES

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO65A01	Unnamed Trib. to Muddy Creek	08010207 Upper Hatchie	South Central Mississippi River	McNairy	35.09583	-88.49944
ECO65A03	Wardlow Creek	06040001 TN Western Valley	Tennessee River	McNairy	35.02277	-88.44194
ECO65B04	Cypress Creek	08010207 Upper Hatchie	South Central Mississippi River	Hardeman	35.0675	-88.86
ECO65E04	Blunt Creek	06040005 TN Western Valley	Tennessee River	Carroll	35.95916	-88.26805
ECO65E06	Griffin Creek	08010204 S Fork Forked Deer	South Central Mississippi River	Henderson/Carroll	35.1861	-88.54055
ECO65E08	Harris Creek	08010201 N Fk Forked Deer	South Central Mississippi River	Madison	35.62638	-88.69972
ECO65E10	Marshall Creek	08010208 Lower Hatchie	South Central Mississippi River	Hardeman	35.16138	-89.01694
ECO65E11	West Fork Spring Creek	08010208 Lower Hatchie	South Central Mississippi River	Hardeman	35.10194	-89.08194
ECO65I02	Battles Branch	06030005 TN Pickwick Lake	Tennessee River	Hardin	35.03333	-88.29305
ECO65J04	Pompeys Branch	06030005 TN Pickwick Lake	Tennessee River	Hardin	35.05388	-88.16805
ECO65J05	Dry Creek	06030005 TN Pickwick Lake	Tennessee River	Hardin	35.035	-88.15222
ECO65J06	Right Fork Whites Creek	06040001 TN Western Valley	Tennessee River	Hardin	35.05305	-88.04777
ECO65J11	Unnamed Trib. Rt Fork Whites Cr	06040001 TN Western Valley	Tennessee River	Hardin	35.05225	-88.04825

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO66D01	Black Branch	06010103 Watauga	Tennessee River	Carter	36.2825	-82.0275
ECO66D03	Laurel Fork	06010103 Watauga	Tennessee River	Carter	36.25694	-82.11111
ECO66D05	Doe River	06010103 Watauga	Tennessee River	Carter	36.15888	-82.10583
ECO66D06	Tumbling Creek	06010108 Nolichucky	Tennessee River	Carter	36.01805	-82.48194
ECO66D07	Little Stoney Creek	06010103 Watauga	Tennessee River	Carter	36.28666	-82.06666
ECO66E04	Gentry Creek	06010102 South Fork Holston	Tennessee River	Johnson	36.54444	-81.72444
ECO66E09	Clark Creek	06010108 Nolichucky	Tennessee River	Unicoi	36.14722	-82.52861
ECO66E11	Lower Higgens Creek	06010108 Nolichucky	Tennessee River	Unicoi	36.08722	-82.52027
ECO66E17	Double Branch	06010201 Fort Loudoun Lake	Tennessee River	Blount	35.74444	-83.76388
ECO66E18	Gee Creek	06020002 Hiwassee	Tennessee River	Polk	35.24444	-84.54388
ECO66F06	Abrams Creek	06010204 Little Tennessee	Tennessee River	Blount	35.59305	-83.84694
ECO66F07	Beaverdam Creek	06010102 South Fork Holston	Tennessee River	Johnson	36.58638	-81.8275
ECO66F08	Stony Creek	06010103 Watauga	Tennessee River	Carter	36.46722	-81.99805
ECO66G04	Middle Prong Little Pigeon R	06010107 Lower French Broad	Tennessee River	Sevier	35.70666	-83.37888

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO66G05	Little River	06010201 Ft Loudoun/Little R	Tennessee River	Sevier	35.6525	-83.5775
ECO66G07	Citico Creek	06010204 Little Tennessee	Tennessee River	Monroe	35.50555	-84.10694
ECO66G09	North River	06010204 Little Tennessee	Tennessee River	Monroe	35.32777	-84.14583
ECO66G12	Sheeds Creek	03150101 Conasauga	Tennessee River	Polk	35.00305	-84.61222
ECO67F06	Clear Creek	06010207 Lower Clinch	Tennessee River	Anderson	36.21361	-84.05972
ECO67F13	White Creek	06010205 Upper Clinch	Tennessee River	Union	36.34361	-83.89166
ECO67F14	Powell River	06010206 Powell	Tennessee River	Hancock	36.55638	-83.37916
ECO67F16	Hardy Creek	06010206 Powell	Tennessee River	Lee County, VA	36.65083	-83.24722
ECO67F17	Big War Creek	06010205 Upper Clinch	Tennessee River	Hancock	36.42694	-83.34694
ECO67F23	Martin Creek	06010206 Powell	Tennessee River	Hancock	36.59111	-83.335
ECO67F25	Powell River	06010206 Powell	Tennessee River	Claiborne	36.55638	-83.60194
ECO67G01	Little Chucky	06010108 Nolichucky	Tennessee River	Greene	36.12388	-83.05305
ECO67G05	Bent Creek	06010108 Nolichucky	Tennessee River	Hamblen	36.18888	-83.16333
ECO67G08	Brymer Creek	06020002 Hiwassee	Tennessee River	Bradley	35.12666	-84.96388

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO67G09	Harris Creek	06020002 Hiwassee	Tennessee River	Bradley	35.175	-84.97916
ECO67H04	Blackburn Creek	06020002 Hiwassee	Tennessee River	Bradley	35.22472	-84.97055
ECO67H06	Laurel Creek	06010204 Little Tennessee	Tennessee River	Monroe	35.44829	-84.28833
ECO67H08	Parker Branch	06010104 Holston	Tennessee River	Hawkins	36.5225	-82.65888
ECO67I12	Mill Creek	06010207 Lower Clinch	Tennessee River	Anderson	35.98833	-84.28888
ECO6701	Big Creek	06010104 Holston	Tennessee River	Hawkins	36.4975	-82.9175
ECO6702	Fisher Creek	06010104 Holston	Tennessee River	Hawkins	36.49	-82.94027
ECO6707	Possum Creek	06010102 South Fork Holston	Tennessee River	Sullivan	36.48	-82.19944
ECO68A01	Rock Creek	05130104 S Fork Cumberland	Cumberland River	Pickett	36.57833	-84.79472
ECO68A03	Laurel Fork of Station Camp Cr	05130104 S Fork Cumberland	Cumberland River	Fentress/Scott	36.51611	-84.69805
ECO68A08	Clear Creek	06010208 Emory	Tennessee River	Morgan	36.11916	-84.7425
ECO68A13	Piney Creek	06010201 Watts Bar Lake	Tennessee River	Rhea	35.62083	-84.96944
ECO68A20	Mullens Creek	06020001 Tennessee	Tennessee River	Marion	35.12472	-85.44388
ECO68A26	Daddy’s Creek	06010208 Emory	Tennessee River	Cumberland	36.05861	-84.79138

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO68A27	Island Creek	06010208 Emory	Tennessee River	Morgan	36.05138	-84.66805
ECO68A28	Rock Creek	06010208 Emory	Tennessee River	Morgan	36.13277	-84.64166
ECO68B01	Crystal Creek	06020004 Sequatchie	Tennessee River	Bledsoe	35.54083	-85.21694
ECO68B02	McWilliams Creek	06020004 Sequatchie	Tennessee River	Sequatchie	35.4175	-85.32083
ECO68B09	Mill Branch	06020004 Sequatchie	Tennessee River	Bledsoe	35.67444	-85.08888
ECO68C12	Ellis Gap Branch	06020001 Tennessee	Tennessee River	Marion	35.04916	-85.47277
ECO68C13	Mud Creek	06030003 Upper Elk	Tennessee River	Franklin	35.23055	-85.91722
ECO68C15	Crow Creek	06030001 Guntersville Lake	Tennessee River	Franklin	35.1138	-85.9128
ECO68C20	Crow Creek	06030001 Guntersville Lake	Tennessee River	Franklin	35.1155	-85.9110
ECO69D01	No Business Branch	05130101 Upper Cumberland	Cumberland River	Campbell	36.55277	-84.6861
ECO69D03	Flat Fork	06010208 Emory	Tennessee River	Morgan	36.1235	-84.5122
ECO69D04	Stinking Creek	05130101 Upper Cumberland	Cumberland River	Campbell	36.4258	-84.2618
ECO69D05	New River	05140104 S Fork Cumberland	Cumberland River	Morgan	36.12444	-84.43130
ECO69D06	Round Rock Creek	05130104 S Fork Cumberland	Cumberland River	Campbell	36.24722	-84.28444

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO71E09	Buzzard Creek	05130206 Red	Cumberland River	Robertson	36.60583	-86.98361
ECO71E14	Passenger Creek	05130206 Red	Cumberland River	Montgomery	36.53444	-87.19583
ECO71F12	South Harpeth River	05130204 Harpeth	Cumberland River	Williamson	35.92416	-87.09416
ECO71F16	Wolf Creek	06040003 Lower Duck	Tennessee River	Hickman	35.81805	-87.68527
ECO71F19	Brush Creek	06040004 Buffalo	Tennessee River	Lewis/Lawrence	35.41972	-87.53416
ECO71F27	Swanegan Branch	06030005 Pickwick Lake	Tennessee River	Wayne	35.06916	-87.6375
ECO71F28	Little Swan Creek	06040003 Lower Duck	Tennessee River	Lewis	35.52888	-87.45361
ECO71G03	Flat Creek	05130106 Upper Cumberland	Cumberland River	Overton/Putnam	36.35944	-85.43138
ECO71G04	Spring Creek	05130106 Upper Cumberland	Cumberland River	Overton/Putnam	36.27277	-85.42333
ECO71G10	Hurricane Creek	06030003 Upper Elk	Tennessee River	Moore	35.32083	-86.29944
ECO71H03	Flynn Creek	05130106 Upper Cumberland	Cumberland River	Jackson	36.27972	-85.66444
ECO71H06	Clear Fork	05130108 Caney Fork	Cumberland River	Dekalb/Cannon	35.92416	-85.99083
ECO71H09	Carson Fork	05130203 Stones	Cumberland River	Cannon	35.75111	-86.13055
ECO71I03	Stewart Creek	05130203 Stones	Cumberland River	Rutherford	35.89805	-86.55777

SITE #	STREAM	USGS HUC	MAJOR BASIN	COUNTY	LATITUDE	LONGITUDE
ECO71I09	West Fork Stones River	05130203 Stones	Cumberland River	Rutherford	35.70277	-86.46527
ECO71I10	Flat Creek	06040002 Upper Duck	Tennessee River	Marshall	35.68583	-86.80166
ECO71I12	Cedar Creek	05130201 Cumberland	Cumberland River	Wilson	36.28425	-86.20339
ECO71I13	Fall Creek	05130203 Stones	Cumberland River	Rutherford	36.02894	-86.41381
ECO71I14	Little Flat Creek	06040002 Upper Duck	Tennessee River	Maury	35.69903	-86.83872
ECO71I15	Harpeth River	05130204 Harpeth	Cumberland River	Williamson	35.83272	-86.70019
ECO73A01	Cold Creek	08010100 Mississippi	South Central Mississippi River	Lauderdale	35.44330	-89.41580
ECO73A02	Middle Fork Forked Deer	08010100 Mississippi	South Central Mississippi	Lauderdale	35.81777	-89.65611
ECO73A03	Cold Creek	08010100 Mississippi	South Central Mississippi	Lauderdale	35.66305	-89.81222
ECO73A04	Bayou du Chien	08010202 Obion	South Central Mississippi River	Lake	36.475	-89.30916
ECO74A06	Sugar Creek	08010100 Mississippi	South Central Mississippi River	Tipton	35.49944	-89391888
ECO74A08	Pawpaw Creek	08010202 Obion	South Central Mississippi River	Obion	36.30527	-89.35666
ECO74B01	Terrapin Creek	08010202 Obion	South Central Mississippi River	Henry	36.48666	-88.48583
ECO74B04	Powell Creek	08010202 Obion	South Central Mississippi River	Weakley	36.48027	-88.64
ECO74B12	Wolf River	08010210 Wolf	South Central Mississippi River	Fayette	35.0325	-89.24583

APPENDIX C

ECOREGIONAL SITES DROPPED FROM REFERENCE CONSIDERATION

ECO65B05 Prairie Branch, Hardeman Co. – Dropped 4th quarter FY98 by Jackson Environmental Assistance Center (JEAC). The portion of this subregion in Tennessee is extremely small. Only two streams were targeted for monitoring, to see if 65b stream characteristics were different from 65e. Both selected streams were known to be impaired prior to monitoring, but were the only ones available in the subregion. Biometrics from ECO65B05 showed no overlap with ECO65B04 at the 75th percentile.

ECO65I01 Robinson Creek, Hardin Co. - The portion of this subregion in Tennessee is extremely small. Suitable reference sites could not be located. Streams were monitored to determine whether 65i characteristics were different from 65e.

ECO65I03 Unnamed Trib to East Fork Robinson Creek, Hardin Co. – The portion of this subregion in Tennessee is extremely small. Suitable reference sites could not be located. Streams were monitored to determine whether 65i characteristics were different from 65e.

ECO67F08 Little Sewee Creek, Meigs Co. – Dropped by Chattanooga Environmental Assistance Center (CHEAC) after initial sampling due to impacts from agriculture and urban development. Seven other sites are being monitored in the same subregion.

ECO67F26 Indian Creek, Claiborne Co. - Dropped by Knoxville Environmental Assistance Center (KEAC) after sampling two seasons in 1997. Benthic results were not consistent with other reference sites. Impacts cited included heavy cattle use and excessive sedimentation. Seven other reference sites are being monitored in the same subregion.

ECO67I11 Thompson Creek, McMinn Co. - Only 2 streams were selected in this small subregion. Benthic data from Thompson Creek indicated a stressed community that was significantly different from the other reference stream. Field notes indicated residential and agricultural impacts with a high sediment load. Habitat scores were also comparatively low.

ECO68A21 Firescald Creek, Grundy Co. - Dropped after initial sampling due to impacts from upstream impoundment. There are eight other streams being monitored in the same subregion.

ECO68C19 Unnamed Trib. in Pauley King Cove, Marion Co. - This stream was monitored a single time to compare the benthic community in a sandstone based stream to the limestone base present in all other selected reference streams in region. The benthic community was not similar to that found in the limestone reference streams. Additional sandstone streams would need to be monitored to determine if this is comparable to the reference quality limestone streams or if the benthic community was stressed.

ECO71E01 Noah Springs Branch, Montgomery Co. - Site was dropped by Nashville Environmental Assistance Center (NEAC) due to hydrologic impacts from road culverts upstream. The only available sampling site was downstream of the culverts due to the upstream area being in the Ft. Campbell bombing range.

ECO71E15, Little West Fork, Montgomery Co. - Site was dropped by NEAC due to poor benthic community. According to field notes, excessive sediment was present in the stream.

ECO71F01, Panther Creek, Stewart Co. – This is a small stream with a very unstable gravel substrate. NCBI and Clinger scores fell outside the interquartile range compared to other sites in the subregion. Five other sites are being monitored in the same subregion.

ECO71F26, Pryor Creek, Stewart Co. – Dropped by NEAC due to the small watershed size. Five other sites are being monitored in the same subregion

ECO71G05, Cherry Creek, White Co. – Dropped by NEAC. What started as minor sediment impact from agriculture and development became more serious as the project progressed. Three other sites are being monitored in 71g.

ECO71G11, West Fork Long Creek, Macon Co. - Dropped by NEAC initially due to a poor macroinvertebrate community. Confirmed by statistical comparison to other sites, NCBI and %OC are outside 90^{th} percentile for the region. Excessive siltation and filamentous algae were observed during some visits.

ECO71H15 West Harpeth River, Williamson Co., - Dropped by NEAC due to siltation and interstate impacts.

ECO74A10 Unnamed Trib to Running Reelfoot Bayou, Obion Co., - Small, atypical for subregion, macroinvertebrate population more indicative of a spring than a creek.

APPENDIX D

BIOMETRIC AND INDEX SCORES FOR ECOREGIONAL REFERENCE SITES USED IN BIOCRITERIA DETERMINATIONS

StationID	CollMeth	Date	TR	EPT		%OC	NCBI	%Dom	%Cling	Index
ECO65A01	SQBANK	9/9/96	27	1	10.7	34.2	7.18	27.1	19.1	22
ECO65A01	SQBANK	4/28/97	33	8	52.9	24.3	5.62	17.5	11.1	34
ECO65A01	SQBANK	9/8/97	31	4	30.2	21.8	6.13	17.3	22.3	30
ECO65A03	SQBANK	9/20/96	28	3	14.2	24.0	6.31	16.4	18.4	26
ECO65A03	SQBANK	4/15/97	38	2	8.3	25.0	6.83	26.2	28.0	26
ECO65A03	SQBANK	9/9/97	25	6	28.5	14.5	5.36	27.9	29.6	32
ECO65B04	SQBANK	9/16/96	26	8	71.6	17.3	6.04	45.7	16.8	30
ECO65B04	SQBANK	4/14/97	41	9	46.6	45.3	5.82	14.9	11.2	34
ECO65B04	SQBANK	9/8/97	34	5	40.4	42.1	5.00	28.7	20.2	34
ECO65B04	SQBANK	4/23/98	40	9	42.3	38.9	6.29	22.3	18.3	34
ECO65B04	SQBANK	9/2/98	38	5	27.7	42.0	5.12	14.7	29.0	34
ECO65B04	SQBANK	4/7/99	39	7	15.3	67.7	6.40	23.3	5.3	24
ECO65E02	SQBANK	4/15/97	48	13	16.7	70.6	6.26	23.5	9.0	26
ECO65E02	SQBANK	9/10/97	40	10	33.3	50.0	5.10	23.9	22.6	36
ECO65E04	SQBANK	4/17/97	47	11	17.8	67.0	5.80	30.5	22.3	32
ECO65E04	SQBANK	10/7/97	40	9	27.4	53.0	5.69	24.4	19.0	32
ECO65E04	SQBANK	4/22/98	41	13	14.1	74.5	5.97	22.3	22.8	30
ECO65E04	SQBANK	9/5/98	26	6	27.7	52.0	4.93	32.2	23.8	30
ECO65E04	SQBANK	4/19/99	37	11	21.8	71.1	5.40	18.0	35.1	34
ECO65E06	SQBANK	4/16/97	39	10	47.7	39.7	4.41	29.3	36.2	42
ECO65E06	SQBANK	9/10/97	52	9	22.1	56.3	5.40	25.4	27.7	32
ECO65E06	SQBANK	4/22/98	31	14	28.1	61.4	5.18	26.8	24.6	34
ECO65E06	SQBANK	9/9/98	35	9	7.0	77.9	6.20	45.9	14.5	20
ECO65E06	SQBANK	4/19/99	40	11	20.7	68.7	5.65	24.0	14.5	30
ECO65E08	SQKICK	9/10/96	33	4	15.8	55.5	5.91	17.7	29.2	26
ECO65E08	SQBANK	5/5/97	24	8	81.6	16.6	6.34	58.5	10.6	26
ECO65E08	SQBANK	8/15/97	29	7	16.2	71.3	6.27	26.9	37.1	28
ECO65E08	SQBANK	6/2/98	46	11	45.5	45.1	6.44	33.0	21.0	36
ECO65E08	SQBANK	9/10/98	32	6	13.7	59.7	5.82	14.7	40.3	32
ECO65E08	SQBANK	3/24/99	33	8	26.4	57.7	4.96	21.6	31.3	34
ECO65E10	SQBANK	8/9/96	39	8	44.5	48.0	3.37	35.5	42.0	36
ECO65E10	SQBANK	9/16/96	60	10	18.2	49.2	5.81	9.5	19.0	30
ECO65E10	SQBANK	4/17/97	31	7	27.7	66.2	4.34	9.5	24.6	30
ECO65E10	SQBANK	8/14/97	37	14	58.5	28.5	4.14	22.5	37.0	40
ECO65E10	SQBANK	4/23/98	50	14	28.6	44.1	5.43	15.5	23.0	36
ECO65E10	SQBANK	9/2/98	37	8	46.5	41.2	3.93	37.6	42.9	36
ECO65E11	SQBANK	8/15/96	28	9	21.1	43.5	5.83	17.0	17.0	30
ECO65E11	SQBANK	9/16/96	54	8	12.1	37.4	6.33	14.6	12.1	32
ECO65E11	SQBANK	4/17/97	37	8	7.5	25.8	7.28	37.5	2.1	30

StationID	CollMeth	Date	TR	EPT	%EPT	%OC	NCBI	%Dom	%Cling	Index
ECO65E11	SQBANK	8/14/97	45	10	19.0	43.1	6.32	13.8	20.7	34
ECO65E11	SQBANK	4/23/98	38	5	4.4	40.8	6.90	27.2	5.3	24
ECO65E11	SQBANK	9/2/98	43	10	25.5	31.9	5.69	13.0	19.9	36
ECO65E11	SQBANK	4/7/99	50	11	15.2	42.1	5.90	10.7	14.6	32
ECO65I02	SQKICK	9/18/96	25	5	66.8	25.1	4.45	57.8	76.7	32
ECO65I02	SQKICK	4/15/97	25	6	28.4	46.6	5.19	21.6	46.0	32
ECO65I02	SQKICK	10/7/97	34	4	30.6	49.6	5.31	19.4	35.1	32
ECO65J04	SQKICK	8/29/96	37	13	51.4	14.8	3.56	18.1	70.4	40
ECO65J04	SQKICK	5/2/97	38	18	59.3	27.4	3.34	18.1	41.2	36
ECO65J04	SQKICK	8/21/97	27	12	67.6	15.6	3.56	17.9	57.2	40
ECO65J04	SQKICK	4/29/98	49	16	61.3	20.1	2.87	11.9	54.1	34
ECO65J04	SQKICK	9/17/98	30	12	60.6	22.4	4.05	18.8	41.8	38
ECO65J04	SQKICK	4/20/99	27	14	62.7	21.2	2.79	10.4	59.0	40
ECO65J05	SQKICK	8/29/96	27	11	64.2	10.4	3.94	27.9	36.3	38
ECO65J05	SQKICK	5/2/97	37	13	34.9	34.9	3.86	21.4	37.6	36
ECO65J05	SQKICK	8/21/97	29	12	38.3	24.5	4.38	12.8	44.4	36
ECO65J05	SQKICK	5/9/98	30	11	30.0	36.1	4.00	30.0	57.2	36
ECO65J05	SQKICK	9/17/98	40	7	25.9	60.8	5.53	14.5	44.6	28
ECO65J05	SQKICK	8/31/99	35	12	45.6	38.5	4.05	23.6	27.7	32
ECO65J06	SQKICK	8/29/96	49	12	29.5	51.5	4.63	16.5	34.5	34
ECO65J06	SQKICK	5/2/97	25	6	45.2	38.9	4.23	26.0	21.2	26
ECO65J06	SQKICK	8/22/97	34	10	45.0	34.2	4.14	14.9	50.9	36
ECO65J06	SQKICK	4/28/98	33	12	28.2	51.5	3.05	25.1	39.6	32
ECO65J06	SQKICK	9/17/98	27	10	26.1	26.7	4.35	43.9	61.1	32
ECO65J06	SQKICK	4/29/99	25	11	18.0	28.7	4.06	51.1	66.3	32
ECO65J11	SQKICK	5/2/97	35	10	33.5	53.6	4.66	18.3	18.8	28
ECO65J11	SQKICK	8/22/97	33	13	40.5	46.7	4.40	31.9	44.3	34
ECO65J11	SQKICK	4/29/98	32	12	61.2	17.3	2.76	16.8	71.5	40
ECO65J11	SQKICK	9/17/98	25	6	8.3	59.4	4.87	37.5	39.6	18
ECO65J11	SQKICK	4/29/99	22	8	7.9	66.8	4.72	43.9	29.9	18
ECO66D01	SQKICK	9/18/96	35	16	73.7	8.0	3.06	13.1	59.6	42
ECO66D01	SQKICK	4/25/97	45	20	53.2	20.7	2.73	14.4	65.8	42
ECO66D01	SQKICK	9/26/97	42	15	35.3	27.5	3.69	9.2	49.3	36
ECO66D01	SQKICK	5/15/98	35	16	55.5	23.7	2.61	14.5	54.9	36
ECO66D01	SQKICK	10/7/98	39	12	32.2	28.2	3.81	14.1	44.6	34
ECO66D01	SQKICK	4/19/99	39	13	35.8	25.4	3.18	15.5	54.9	34
ECO66D03	SQKICK	9/18/96	50	15	33.0	26.3	3.97	12.4	63.2	38
ECO66D03	SQKICK	4/25/97	40	18	63.5	18.8	3.03	16.5	64.1	42
ECO66D03	SQKICK	9/15/97	40	16	40.3	32.3	3.49	9.7	57.0	38
ECO66D03	SQKICK	4/13/98	38	22	79.0	6.8	1.89	19.9	85.8	42

StationID	CollMeth	Date	TR	EPT	%EPT	%OC	NCBI	%Dom	%Cling	Index
ECO66D03	SQKICK	10/9/98	33	20	87.6	4.3	1.88	17.3	72.4	40
ECO66D03	SQKICK	4/19/99	38	19	58.3	10.8	2.44	10.3	69.5	42
ECO66D05	SQKICK	6/23/97	33	15	64.9	12.6	2.96	19.5	55.7	40
ECO66D05	SQKICK	11/5/97	33	16	75.9	15.7	2.32	28.8	72.8	40
ECO66D05	SQKICK	5/15/98	32	13	39.7	55.9	3.53	23.1	24.9	28
ECO66D05	SQKICK	9/15/98	32	17	77.0	11.2	3.36	19.4	62.2	40
ECO66D05	SQKICK	4/22/99	31	13	76.0	18.4	2.12	15.8	67.9	38
ECO66D06	SQKICK	11/7/97	40	18	52.6	26.3	2.76	16.0	59.4	40
ECO66D07	SQKICK	11/5/97	42	20	67.9	12.8	2.23	18.7	56.1	42
ECO66E04	SQKICK	11/6/97	31	16	79.1	15.3	1.94	25.5	75.0	40
ECO66E09	SQKICK	9/9/96	32	15	79.3	6.5	3.51	23.0	67.3	40
ECO66E09	SQKICK	5/5/97	40	20	62.7	29.4	3.00	10.7	55.4	42
ECO66E09	SQKICK	8/22/97	36	18	77.7	11.9	2.83	14.4	60.9	42
ECO66E09	SQKICK	5/13/98	33	17	75.9	10.2	2.19	25.3	62.7	40
ECO66E09	SQKICK	4/7/99	35	17	41.5	13.5	2.96	30.4	70.8	40
ECO66E11	SQKICK	9/5/96	37	20	71.7	15.1	2.20	16.3	73.7	42
ECO66E11	SQKICK	5/23/97	36	18	66.8	20.2	3.34	25.9	42.0	40
ECO66E11	SQKICK	8/21/97	35	13	58.5	15.8	2.73	27.5	70.8	40
ECO66E11	SQKICK	4/2/98	29	14	65.0	8.3	1.77	19.4	83.3	38
ECO66E11	SQKICK	9/10/98	40	17	69.0	12.5	3.02	14.9	60.7	42
ECO66E11	SQKICK	6/9/99	38	19	70.1	11.4	2.76	15.8	63.0	42
ECO66E17	SQKICK	9/30/97	47	18	54.8	17.0	3.57	11.7	62.2	40
ECO66E18	SQKICK	9/10/96	43	17	26.2	54.8	3.17	19.0	35.2	32
ECO66E18	SQKICK	4/14/97	38	14	33.5	48.1	3.27	13.0	36.8	32
ECO66E18	SQKICK	9/16/97	39	19	56.0	18.1	2.65	13.3	50.6	38
ECO66F06	SQKICK	9/3/96	36	16	48.0	10.8	3.08	19.2	68.4	40
ECO66F06	SQKICK	5/20/97	30	17	71.2	7.4	2.14	20.9	81.0	40
ECO66F06	SQKICK	9/30/97	29	9	44.9	6.3	3.30	20.5	82.4	34
ECO66F06	SQKICK	4/13/98	21	10	54.4	13.3	2.41	21.7	83.9	32
ECO66F06	SQKICK	8/28/98	32	14	64.8	10.1	3.48	18.4	65.4	38
ECO66F06	SQKICK	4/22/99	28	11	54.4	8.8	2.41	19.2	73.6	36
ECO66F07	SQKICK	9/19/96	47	16	46.1	31.6	3.83	11.8	43.4	36
ECO66F07	SQKICK	6/10/97	30	18	78.7	13.4	3.00	31.7	35.4	36
ECO66F07	SQKICK	10/13/97	37	22	82.9	9.4	2.58	11.8	72.9	42
ECO66F08	SQKICK	11/7/97	41	21	56.9	19.9	2.56	13.3	58.8	38
ECO66G04	SQKICK	9/4/96	44	17	28.6	62.0	4.45	22.9	38.0	30
ECO66G04	SQKICK	10/2/97	42	21	71.1	14.4	3.14	12.2	72.8	42
ECO66G05	SQKICK	9/4/96	35	17	69.9	22.5	3.02	36.8	27.8	40
ECO66G05	SQKICK	5/19/97	36	22	60.6	8.0	2.55	23.4	60.6	42
ECO66G05	SQKICK	10/2/97	25	22	97.0	0.0	2.41	14.8	63.3	40

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO66G05	SQKICK	4/13/98	29	13	80.0	14.1	1.45	29.4	75.3	38
ECO66G05	SQKICK	9/11/98	24	14	76.8	17.5	3.30	18.1	37.9	36
ECO66G05	SQKICK	4/22/99	40	20	57.5	28.1	2.45	16.2	60.5	40
ECO66G07	SQKICK	10/1/97	30	10	53.1	8.6	4.13	17.7	73.1	34
ECO66G07	SQKICK	4/16/98	37	16	36.2	23.7	3.90	24.6	73.9	38
ECO66G07	SQKICK	9/10/98	28	13	53.3	26.4	4.35	14.3	71.4	34
ECO66G07	SQKICK	4/8/99	35	13	28.9	17.1	4.11	29.8	78.5	34
ECO66G09	SQKICK	10/1/97	40	16	62.4	11.9	2.89	9.6	69.7	42
ECO66G09	SQKICK	5/18/98	44	21	62.1	20.7	2.51	9.8	70.1	42
ECO66G09	SQKICK	9/10/98	38	18	57.1	30.5	3.82	10.3	48.8	36
ECO66G09	SQKICK	4/8/99	38	19	62.4	23.7	3.28	11.6	60.1	42
ECO66G12	SQKICK	9/12/96	47	16	40.4	36.5	3.95	6.1	47.6	36
ECO66G12	SQKICK	4/15/97	40	17	53.6	37.3	3.17	18.7	58.4	38
ECO66G12	SQKICK	9/8/97	47	16	45.0	28.6	3.81	9.5	42.0	38
ECO66G12	SQKICK	5/13/98	37	14	54.1	27.9	3.05	15.7	44.2	36
ECO66G12	SQKICK	8/31/98	48	18	50.0	21.5	3.91	18.6	45.9	38
ECO66G12	SQKICK	4/26/99	36	16	66.3	20.8	2.95	11.2	60.1	42
ECO6701	SQKICK	5/29/98	35	13	17.1	35.7	4.45	23.8	61.4	36
ECO6701	SQKICK	9/22/98	23	8	51.9	4.4	3.99	24.9	83.4	38
ECO6701	SQKICK	4/16/99	31	14	36.6	27.4	3.88	14.0	66.1	38
ECO6702	SQKICK	10/1/96	41	16	41.7	41.7	4.32	12.0	49.1	36
ECO6702	SQKICK	6/18/97	36	11	38.4	42.9	4.78	19.2	38.9	32
ECO6702	SQKICK	8/29/97	27	8	47.9	27.3	4.26	9.7	47.9	34
ECO6702	SQKICK	5/29/98	31	12	37.2	25.0	4.73	11.6	65.1	38
ECO6702	SQKICK	9/22/98	29	13	55.4	21.1	4.51	20.5	62.7	40
ECO6702	SQKICK	4/16/99	31	14	38.0	23.4	3.67	13.5	67.8	40
ECO6707	SQKICK	5/13/98	35	16	68.8	14.8	2.79	28.0	77.2	42
ECO6707	SQKICK	9/14/98	28	11	75.3	12.6	4.68	31.9	65.9	38
ECO6707	SQKICK	4/22/99	37	14	57.0	4.5	4.03	14.0	40.5	40
ECO67F06	SQKICK	5/5/98	31	16	55.1	4.0	2.77	25.8	64.1	42
ECO67F06	SQKICK	8/31/98	27	10	34.1	2.0	4.09	30.2	59.0	36
ECO67F06	SQKICK	4/20/99	34	16	48.5	16.2	3.12	15.7	47.2	40
ECO67F13	SQKICK	9/5/96	20	10	31.3	1.4	4.50	23.7	55.5	34
ECO67F13	SQKICK	5/5/97	23	12	39.9	1.2	2.93	58.5	58.5	36
ECO67F13	SQKICK	9/11/97	22	10	32.5	3.7	4.33	57.1	23.0	36
ECO67F13	SQKICK	5/6/98	23	12	33.3	1.1	4.17	26.7	60.6	38
ECO67F13	SQKICK	8/31/98	27	14	45.8	3.0	3.57	17.9	68.5	40
ECO67F13	SQKICK	4/20/99	20	12	50.3	1.2	3.58	13.6	65.7	38
ECO67F14	SQKICK	9/20/96	27	9	50.7	10.2	4.05	19.4	54.4	38
ECO67F14	SQKICK	6/27/97	28	7	27.3	19.1	4.62	35.9	71.3	30

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO67F14	SQKICK	10/2/97	24	8	28.0	4.0	3.64	32.0	71.0	34
ECO67F14	SQKICK	3/31/98	39	17	43.1	17.4	3.96	13.8	56.9	40
ECO67F14	SQKICK	9/1/98	23	9	32.8	5.1	3.85	30.8	60.6	36
ECO67F16	SQKICK	5/22/98	22	10	40.2	7.0	3.27	37.1	54.1	32
ECO67F16	SQKICK	9/24/98	32	14	48.4	10.3	3.82	17.9	56.5	42
ECO67F16	SQKICK	4/1/99	44	21	52.8	8.5	3.54	11.1	59.6	42
ECO67F17	SQKICK	9/25/96	29	9	50.2	26.0	4.31	25.1	44.8	36
ECO67F17	SQKICK	6/13/97	35	12	43.0	28.7	4.30	13.9	49.1	38
ECO67F17	SQKICK	9/12/97	26	9	47.9	17.0	4.05	14.4	63.3	38
ECO67F17	SQKICK	5/28/98	41	13	21.8	38.2	4.60	20.6	55.3	36
ECO67F17	SQKICK	10/2/98	29	10	48.7	14.0	4.00	14.0	72.5	38
ECO67F17	SQKICK	5/28/99	29	12	40.9	15.5	4.04	17.6	64.2	38
ECO67F23	SQKICK	5/22/98	30	11	54.0	15.5	3.72	19.5	34.5	34
ECO67F23	SQKICK	9/24/98	26	12	61.1	8.4	3.13	24.0	61.7	40
ECO67F23	SQKICK	4/1/99	34	14	32.7	9.9	2.82	35.9	74.9	38
ECO67G01	SQKICK	12/2/96	28	7	59.3	24.8	4.44	31.1	52.2	32
ECO67G01	SQKICK	5/12/97	32	10	19.0	56.4	5.06	17.9	47.7	36
ECO67G01	SQKICK	8/22/97	24	9	50.0	21.3	4.82	15.2	53.4	38
ECO67G01	SQKICK	5/14/98	32	3	3.6	39.6	5.27	46.4	55.2	28
ECO67G01	SQKICK	9/3/98	24	7	43.2	34.2	5.47	22.1	43.7	34
ECO67G01	SQKICK	5/25/99	22	6	29.7	28.6	4.95	27.6	72.4	34
ECO67G05	SQKICK	9/9/96	36	9	39.0	27.7	5.15	25.1	69.3	40
ECO67G05	SQKICK	5/22/97	24	10	44.9	37.1	5.00	19.7	65.7	36
ECO67G05	SQKICK	9/27/97	27	9	66.1	12.8	3.96	21.6	63.3	42
ECO67G08	SQKICK	5/21/97	26	5	39.6	23.2	5.30	18.8	56.5	38
ECO67G09	SQKICK	10/9/97	29	9	68.2	19.3	4.31	27.3	50.6	40
ECO67H04	SQKICK	9/5/96	25	8	44.2	11.6	4.29	23.6	40.9	34
ECO67H04	SQKICK	5/6/97	29	8	26.1	65.0	1.89	47.8	21.7	24
ECO67H04	SQKICK	10/2/97	23	8	21.4	10.1	4.44	30.4	60.1	34
ECO67H06	SQKICK	9/11/96	43	15	62.3	11.0	4.69	30.5	76.7	40
ECO67H06	SQKICK	9/29/97	35	10	41.0	10.0	4.12	14.8	64.2	38
ECO67H06	SQKICK	5/1/97	41	15	63.2	16.9	3.39	22.9	49.4	40
ECO67H08	SQKICK	9/26/96	38	10	55.9	16.7	2.85	30.4	52.0	38
ECO67H08	SQKICK	4/30/97	24	13	27.3	8.2	5.81	57.9	20.2	28
ECO67H08	SQKICK	10/9/97	38	10	37.1	16.3	4.12	17.4	30.9	34
ECO67I12	SQKICK	9/9/96	42	15	58.9	20.9	4.08	23.6	42.3	40
ECO67I12	SQKICK	4/16/97	49	19	53.0	14.2	3.36	13.2	42.9	40
ECO67I12	SQKICK	9/22/97	31	11	55.1	13.4	4.16	17.6	53.5	38
ECO68A01	SQKICK	9/13/96	32	7	20.3	58.1	4.13	19.7	34.0	28
ECO68A01	SQKICK	5/7/97	38	11	13.2	58.1	4.45	13.2	44.3	30

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO68A01	SQKICK	9/26/97	43	12	41.6	36.7	3.86	24.8	54.0	40
ECO68A01	SQKICK	5/8/98	41	10	27.2	57.4	4.01	16.0	42.0	32
ECO68A01	SQKICK	9/17/98	37	11	30.0	45.9	4.93	8.2	38.2	32
ECO68A01	SQKICK	4/12/99	43	13	33.5	46.6	4.34	14.9	38.5	34
ECO68A03	SQKICK	9/13/96	47	16	47.5	32.3	3.05	10.1	61.8	42
ECO68A03	SQKICK	5/14/97	38	15	39.1	49.1	3.82	14.8	34.9	36
ECO68A03	SQKICK	9/26/97	46	20	57.4	26.2	2.79	10.8	64.6	42
ECO68A03	SQKICK	5/18/98	39	13	48.9	31.3	2.93	16.5	51.6	40
ECO68A03	SQKICK	9/17/98	36	15	50.0	39.5	3.58	14.8	46.9	38
ECO68A03	SQKICK	4/12/99	42	14	54.7	27.9	3.00	15.1	60.3	42
ECO68A08	SQKICK	9/12/96	47	18	32.0	28.0	4.72	14.9	64.7	40
ECO68A08	SQKICK	6/26/97	30	13	36.7	19.9	3.95	21.4	68.9	36
ECO68A08	SQKICK	9/22/97	31	11	43.8	30.2	4.57	12.5	68.2	38
ECO68A08	SQKICK	5/22/98	35	14	45.7	20.6	4.05	13.1	46.3	40
ECO68A08	SQKICK	9/2/98	29	15	32.7	35.1	4.59	17.0	66.7	38
ECO68A08	SQKICK	4/26/99	46	10	28.5	37.3	4.58	14.5	50.3	38
ECO68A13	SQKICK	5/3/99	29	13	39.3	46.8	4.08	32.9	22.5	30
ECO68A20	SQKICK	9/11/96	41	14	43.0	35.5	4.08	19.5	45.0	40
ECO68A20	SQKICK	5/27/97	38	11	31.7	50.3	4.04	10.2	34.1	34
ECO68A20	SQKICK	9/30/97	31	9	48.8	20.9	4.08	31.4	53.5	38
ECO68A20	SQKICK	5/4/98	36	11	38.2	37.6	3.07	11.2	47.1	36
ECO68A20	SQKICK	4/26/99	33	8	32.5	53.8	2.84	26.0	20.7	28
ECO68A26	SQKICK	9/5/97	35	12	49.8	20.1	4.16	13.7	60.3	40
ECO68A26	SQKICK	5/22/98	35	18	57.8	7.0	3.65	29.2	58.4	42
ECO68A26	SQKICK	9/2/98	32	18	57.6	10.0	4.14	14.7	59.4	40
ECO68A26	SQKICK	4/26/99	28	11	45.1	19.0	3.99	17.9	59.8	38
ECO68A27	SQKICK	3/30/98	37	12	38.8	31.1	3.80	18.4	38.3	36
ECO68A27	SQKICK	4/26/99	41	11	39.9	35.4	3.03	20.2	43.3	36
ECO68A28	SQKICK	4/14/98	14	4	13.7	2.7	3.90	76.9	83.0	24
ECO68A28	SQKICK	5/3/99	33	13	30.8	19.8	3.78	23.8	55.8	36
ECO68B01	SQKICK	5/7/97	32	13	72.1	21.2	3.81	30.3	31.5	40
ECO68B01	SQKICK	5/6/98	28	15	84.7	5.3	3.56	35.4	39.2	40
ECO68B01	SQKICK	5/3/99	41	15	49.7	42.0	4.30	14.5	32.6	36
ECO68B02	SQKICK	9/4/96	35	9	30.0	46.6	4.77	10.9	39.7	34
ECO68B02	SQKICK	5/19/97	30	13	60.3	22.3	4.56	27.7	49.5	40
ECO68B02	SQKICK	5/12/98	29	14	69.5	6.3	4.34	23.4	52.3	40
ECO68B02	SQKICK	5/3/99	23	5	24.9	56.0	5.10	18.7	14.5	24
ECO68B09	SQKICK	9/19/96	33	6	27.2	58.3	5.04	18.5	36.1	30
ECO68B09	SQKICK	4/16/97	29	14	62.9	15.8	3.70	22.1	28.3	38
ECO68B09	SQKICK	9/23/97	32	8	22.9	68.7	5.23	29.1	32.6	30

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO68B09	SQKICK	5/5/98	38	12	53.2	13.9	4.34	19.4	34.6	38
ECO68B09	SQKICK	9/8/98	33	9	17.1	70.5	5.31	31.1	36.8	26
ECO68B09	SQKICK	5/3/99	40	8	19.3	69.3	5.17	22.4	31.3	30
ECO68C12	SQKICK	6/3/97	32	8	38.6	17.1	5.42	36.7	22.2	32
ECO68C13	SQKICK	8/23/96	26	5	17.3	37.8	3.70	21.0	58.5	30
ECO68C13	SQKICK	4/16/97	31	9	42.0	57.4	2.50	23.5	75.5	30
ECO68C13	SQKICK	9/3/97	31	9	28.4	8.5	4.84	25.0	53.6	38
ECO68C15	SQKICK	9/6/96	33	8	38.4	31.6	3.92	17.5	55.9	36
ECO68C15	SQKICK	4/16/97	38	12	57.9	19.8	3.23	15.8	54.0	42
ECO68C15	SQKICK	9/3/97	31	8	19.2	56.7	5.01	15.3	46.3	28
ECO68C15	SQKICK	4/14/98	23	13	80.4	3.8	2.82	34.2	48.4	40
ECO68C15	SQKICK	8/31/98	28	10	27.4	59.7	4.76	22.0	50.5	32
ECO68C15	SQKICK	4/28/99	32	13	75.3	11.2	3.17	24.7	44.1	40
ECO68C20	SQKICK	4/14/98	25	9	58.9	8.3	3.85	31.7	35.6	36
ECO68C20	SQKICK	8/31/98	26	6	41.9	24.2	4.05	16.1	49.5	36
ECO68C20	SQKICK	4/28/99	33	10	72.7	9.8	4.57	55.1	10.2	34
ECO69D01	SQKICK	9/10/96	35	13	55.4	24.0	3.28	32.8	67.2	38
ECO69D01	SQKICK	4/25/97	37	11	36.6	23.5	3.49	20.7	37.1	32
ECO69D01	SQKICK	10/3/97	40	14	55.5	24.2	3.85	20.3	62.1	36
ECO69D01	SQKICK	4/2/98	39	14	38.5	32.2	3.52	15.9	34.3	30
ECO69D01	SQKICK	9/1/98	36	11	49.5	33.0	3.84	29.5	65.5	34
ECO69D01	SQKICK	4/9/99	36	14	36.7	36.2	3.61	13.3	38.3	32
ECO69D03	SQKICK	9/12/96	28	11	45.6	27.0	3.53	20.6	58.7	36
ECO69D03	SQKICK	4/17/97	34	12	48.8	37.8	2.68	19.5	45.7	34
ECO69D03	SQKICK	3/20/98	24	15	86.2	9.0	1.51	27.7	81.4	40
ECO69D03	SQKICK	4/30/99	29	14	85.2	11.1	1.12	30.2	78.8	38
ECO69D04	SQKICK	9/21/96	26	7	68.2	9.2	3.76	34.6	70.5	36
ECO69D04	SQKICK	5/16/97	41	20	67.1	20.0	3.80	22.4	35.7	38
ECO69D04	SQKICK	4/2/98	48	21	60.3	18.3	3.58	13.8	50.4	38
ECO69D04	SQKICK	6/5/98	38	14	59.3	18.6	3.98	37.9	66.7	38
ECO69D04	SQKICK	9/1/98	37	11	49.2	22.9	4.19	12.3	57.6	36
ECO69D04	SQKICK	4/9/99	43	18	47.3	11.4	3.45	21.9	65.2	40
ECO69D05	SQKICK	4/6/98	37	22	80.9	11.3	1.90	16.5	72.2	42
ECO69D05	SQKICK	4/30/99	43	18	71.4	21.0	2.73	20.1	48.7	40
ECO69D06	SQKICK	4/6/98	27	14	67.4	10.7	2.43	24.2	72.5	38
ECO69D06	SQKICK	9/16/98	21	9	79.1	5.2	4.30	28.3	74.9	34
ECO69D06	SQKICK	4/9/99	30	12	62.9	20.8	4.05	33.8	37.5	32
ECO71E09	SQKICK	10/1/96	19	7	9.7	0.2	3.48	44.2	76.2	30
ECO71E09	SQKICK	5/19/97	20	4	5.5	19.8	4.25	35.2	68.7	30
ECO71E09	SQKICK	10/16/97	30	9	62.9	5.5	4.83	48.5	85.2	40

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ECO71E09	SQKICK	5/12/98	22	5	4.5	3.4	4.58	40.9	58.5	28
ECO71E09	SQKICK	8/26/98	29	7	27.2	9.4	3.89	34.3	66.7	36
ECO71E09	SQKICK	5/4/99	32	11	43.9	21.4	4.39	12.7	47.4	38
ECO71E14	SQKICK	6/6/97	32	10	50.8	29.4	4.81	20.8	32.0	36
ECO71E14	SQKICK	9/4/97	27	11	53.8	18.7	4.79	23.1	65.4	42
ECO71E14	SQKICK	5/12/98	30	8	57.8	9.4	3.26	22.5	73.8	42
ECO71E14	SQKICK	8/26/98	25	10	69.0	6.5	4.98	20.0	58.5	40
ECO71E14	SQKICK	5/4/99	31	10	42.8	23.2	4.17	13.9	45.4	38
ECO71F12	SQKICK	9/25/96	28	11	54.6	12.3	4.62	16.9	65.4	42
ECO71F12	SQKICK	4/22/97	31	10	41.2	50.3	3.82	28.2	32.2	34
ECO71F12	SQKICK	8/25/97	31	11	51.9	6.4	4.91	19.8	47.6	36
ECO71F12	SQKICK	4/22/98	30	8	22.4	63.5	5.27	26.0	28.1	26
ECO71F12	SQKICK	8/5/98	31	11	65.4	11.2	4.68	20.2	53.2	42
ECO71F12	SQKICK	5/10/99	30	12	31.3	12.3	4.85	34.1	69.3	36
ECO71F16	SQKICK	5/29/98	30	13	37.6	3.2	4.25	18.0	58.2	40
ECO71F16	SQKICK	9/9/98	27	10	41.6	16.3	4.85	17.4	43.7	34
ECO71F16	SQKICK	5/10/99	30	10	30.5	42.9	3.93	32.0	40.4	34
ECO71F19	SQKICK	10/4/96	33	11	50.2	10.3	3.89	20.7	53.6	40
ECO71F19	SQKICK	5/14/97	28	10	58.4	25.9	3.25	22.2	48.1	42
ECO71F19	SQKICK	9/3/97	32	11	68.0	14.6	3.64	19.1	53.4	42
ECO71F19	SQKICK	5/19/98	33	11	54.5	21.4	3.24	31.0	61.0	42
ECO71F19	SQKICK	9/21/98	31	13	58.9	17.3	4.22	27.4	38.6	40
ECO71F19	SQKICK	6/7/99	31	10	35.8	31.3	3.69	19.9	58.5	36
ECO71F27	SQKICK	10/9/96	38	13	45.8	7.5	4.61	18.1	30.0	36
ECO71F27	SQKICK	4/21/97	38	17	44.3	13.9	3.78	16.0	45.9	38
ECO71F27	SQKICK	9/11/97	38	13	22.1	21.6	4.09	32.6	48.4	36
ECO71F27	SQKICK	5/5/98	43	16	52.9	11.5	2.96	18.8	56.7	40
ECO71F27	SQKICK	9/21/98	39	12	33.5	26.9	4.12	13.7	43.4	36
ECO71F27	SQKICK	6/7/99	32	11	47.6	15.3	3.72	13.5	59.4	40
ECO71F28	SQKICK	10/4/96	25	10	53.0	4.8	3.24	29.4	75.4	38
ECO71F28	SQKICK	5/14/97	25	9	32.6	20.1	3.36	17.9	65.2	34
ECO71F28	SQKICK	9/3/97	29	13	66.8	2.4	4.10	27.4	46.6	40
ECO71F28	SQKICK	5/5/98	24	8	43.5	13.6	2.58	28.3	76.6	36
ECO71F28	SQKICK	9/21/98	26	10	63.2	24.7	4.37	17.6	55.6	40
ECO71F28	SQKICK	6/7/99	22	10	62.7	27.6	5.73	29.4	39.9	34
ECO71G03	SQKICK	4/28/98	41	18	41.2	15.5	3.88	13.7	57.1	40
ECO71G03	SQKICK	9/14/98	29	12	56.9	7.4	4.11	26.1	69.1	42
ECO71G03	SQKICK	6/16/99	35	15	35.7	15.0	4.06	26.8	58.2	38
ECO71G04	SQKICK	4/28/98	36	11	65.8	12.2	3.66	20.7	44.7	40
ECO71G04	SQKICK	9/14/98	33	7	55.7	28.9	4.28	22.9	44.3	36

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO71G04	SQKICK	6/16/99	26	9	48.6	9.1	4.28	11.4	54.9	36
ECO71G10	SQKICK	9/30/96	24	9	75.2	3.2	3.70	37.9	49.8	34
ECO71G10	SQKICK	5/1/97	36	14	74.9	16.6	3.01	36.8	43.5	38
ECO71G10	SQKICK	10/10/97	24	9	85.4	4.9	4.53	36.0	67.7	38
ECO71G10	SQKICK	4/23/98	32	13	77.5	8.2	2.60	32.9	51.9	40
ECO71G10	SQKICK	9/8/98	25	11	80.5	6.3	4.07	23.2	67.4	40
ECO71G10	SQKICK	6/8/99	29	13	50.5	12.8	4.28	27.1	75.0	40
ECO71H03	SQKICK	10/14/96	25	12	39.7	2.0	3.22	35.1	75.3	38
ECO71H03	SQKICK	5/6/97	30	12	61.9	6.9	2.43	32.5	70.1	42
ECO71H03	SQKICK	8/20/97	36	11	43.0	17.2	4.77	16.1	38.7	36
ECO71H03	SQKICK	5/4/98	31	14	49.3	2.8	2.15	36.3	84.2	40
ECO71H03	SQKICK	9/17/98	29	11	55.9	21.5	4.30	18.8	60.8	42
ECO71H03	SQKICK	6/2/99	30	11	52.2	23.6	4.35	15.4	36.3	38
ECO71H06	SQKICK	10/16/96	30	11	38.5	8.1	3.33	43.5	61.5	38
ECO71H06	SQKICK	5/12/97	29	8	62.7	23.1	3.07	27.2	43.2	38
ECO71H06	SQKICK	8/21/97	27	14	72.2	13.1	3.44	15.9	50.6	38
ECO71H06	SQKICK	4/13/98	20	8	70.7	2.1	2.59	25.5	62.2	38
ECO71H06	SQKICK	6/11/99	33	10	43.4	45.4	5.29	27.0	21.4	32
ECO71H06	SQKICK	8/31/98	22	9	58.1	19.4	4.35	14.7	40.8	36
ECO71H09	SQKICK	10/16/96	26	10	61.6	15.3	5.19	25.6	46.2	36
ECO71H09	SQKICK	4/30/97	21	10	63.9	14.2	3.68	20.2	33.9	36
ECO71H09	SQKICK	8/19/97	33	15	54.3	12.9	5.11	19.5	40.5	38
ECO71H09	SQKICK	4/13/98	15	8	34.3	1.7	5.71	49.4	32.6	24
ECO71H09	SQKICK	8/31/98	21	10	58.8	9.5	5.53	19.6	34.7	34
ECO71H09	SQKICK	6/11/99	28	10	45.2	20.6	5.22	20.6	37.2	36
ECO71I03	SQKICK	9/26/96	24	5	12.6	74.8	5.49	29.8	19.8	26
ECO71I03	SQKICK	4/23/97	28	9	56.0	21.0	4.19	28.0	37.5	40
ECO71I03	SQKICK	10/1/97	27	3	5.7	51.7	6.05	31.6	24.7	24
ECO71I09	SQKICK	10/8/96	31	7	55.5	12.1	6.74	48.7	21.3	32
ECO71I09	SQBANK	4/23/97	45	12	44.4	24.0	5.81	27.1	24.4	42
ECO71I09	SQKICK	10/1/97	36	4	5.6	46.9	5.57	22.8	13.6	22
ECO71I09	SQBANK	5/19/98	43	8	9.2	26.6	6.64	30.7	6.9	30
ECO71I09	SQBANK	9/1/98	44	8	6.7	60.7	5.87	31.5	31.5	32
ECO71I09	SQBANK	6/3/99	42	6	13.9	32.6	5.80	20.3	22.5	37
ECO71I09	SQKICK	4/19/00	23	6	53.3	28.8	3.97	26.6	51.1	38
ECO71I10	SQBANK	10/18/96	23	2	44.2	10.8	7.22	43.9	16.5	28
ECO71I10	SQBANK	5/1/97	43	8	21.4	57.8	6.80	20.8	9.9	30
ECO71I10	SQBANK	10/9/97	23	2	37.3	5.6	6.99	36.6	23.6	30
ECO71I10	SQBANK	5/19/98	32	3	2.9	39.3	6.56	11.7	16.3	26
ECO71I10	SQBANK	6/8/99	37	5	17.0	12.7	7.20	8.5	27..8	30

StationID	CollMeth	Date	TR	EPT		%OC	NCBI		%Cling	Index
ECO71I10	SQKICK	4/12/00	25	6	20.1	26.1	5.07	18.1	55.3	36
ECO71I12	SQKICK	4/19/00	29	9	38.3	22.1	4.64	19.4	40.5	38
ECO71I12	SQKICK	11/1/00	31	9	19.3	13.5	4.05	24.2	13.5	32
ECO71I13	SQKICK	5/1/00	28	10	38.2	7.8	4.10	24.2	57.4	40
ECO71I13	SQKICK	10/31/00	24	4	27.3	2.1	5.75	26.5	21.0	28
ECO71I14	SQKICK	4/11/00	26	10	48.1	30.6	4.55	21.8	50.8	40
ECO71I15	SQKICK	5/3/00	32	9	44.5	19.8	5.47	28.0	32.2	40
ECO71I15	SQKICK	10/31/00	25	3	16.9	14.8	5.15	26.4	42.9	34
ECO73A01	SQBANK	8/15/96	38	3	16.7	35.9	7.49	15.3	6.7	22
ECO73A01	SQBANK	4/21/97	26	3	7.1	5.9	7.75	20.6	0.6	20
ECO73A01	SQBANK	8/26/97	26	1	38.3	22.9	7.32	38.3	0.6	24
ECO73A02	SQBANK	4/24/97	18	0	0.0	1.7	7.88	0.0	24.7	18
ECO73A02	SQBANK	8/27/97	24	1	2.2	29.1	7.22	20.3	1.1	18
ECO73A02	SQBANK	5/27/98	28	2	27.0	13.8	7.36	24.3	2.1	28
ECO73A02	SQBANK	8/25/98	30	3	35.0	31.1	7.06	34.0	3.9	26
ECO73A02	SQBANK	4/21/99	25	1	1.1	2.1	7.36	58.8	0.5	16
ECO73A03	SQBANK	4/24/97	22	2	2.4	3.3	8.14	32.5	1.0	18
ECO73A03	SQBANK	8/26/97	29	1	1.5	24.9	6.85	25.9	8.5	24
ECO73A03	SQBANK	5/26/98	34	1	4.0	23.7	6.71	18.1	1.1	24
ECO73A03	SQBANK	8/25/98	34	0	0.0	56.1	7.10	24.9	31.2	18
ECO73A03	SQBANK	4/20/99	26	0	0.0	19.2	6.13	26.0	1.1	22
ECO73A04	SQBANK	5/28/98	34	1	6.5	14.6	5.74	14.1	2.5	24
ECO73A04	SQBANK	8/19/98	33	2	19.8	40.5	5.76	18.9	1.4	26
ECO73A04	SQBANK	4/21/99	39	1	0.5	38.5	7.58	17.0	0.5	20
ECO74A06	SQKICK	8/14/96	25	5	65.9	17.0	3.91	39.0	13.9	36
ECO74A06	SQKICK	4/22/97	18	2	1.6	73.7	4.61	57.5	23.1	20
ECO74A06	SQKICK	8/25/97	13	4	70.7	13.8	5.28	58.6	72.4	36
ECO74A06	SQKICK	4/27/98	20	4	4.8	82.6	5.40	53.9	12.6	20
ECO74A06	SQKICK	8/24/98	16	2	23.4	72.9	6.42	25.0	12.5	20
ECO74A06	SQKICK	4/19/99	22	3	7.4	59.7	5.37	19.9	21.3	24
ECO74A08	SQKICK	9/19/96	17	8	89.7	6.1	3.41	42.8	41.8	38
ECO74A08	SQKICK	4/22/97	14	4	7.4	86.7	4.96	74.9	4.4	16
ECO74A08	SQKICK	8/7/97	20	6	84.5	7.9	5.27	37.7	52.3	42
ECO74A08	SQKICK	4/21/98	26	10	41.0	30.3	5.23	15.2	27.0	36
ECO74A08	SQKICK	8/18/98	22	8	62.8	29.8	5.53	40.3	51.3	40
ECO74A08	SQKICK	4/13/99	20	3	39.4	52.6	5.06	29.1	4.6	26
ECO74B01	SQBANK	4/20/98	32	5	27.7	59.8	6.73	25.0	20.1	28
ECO74B01	SQBANK	8/20/98	42	8	36.5	46.6	6.28	16.9	19.1	32
ECO74B01	SQBANK	4/14/99	35	3	13.4	48.7	6.72	18.9	3.4	22
ECO74B04	SQBANK	9/11/96	40	11	35.2	50.7	5.93	16.4	7.0	30

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ECO74B04	SQBANK	5/6/97	52	10	19.0	62.4	5.78	9.5	16.9	32
ECO74B04	SQBANK	4/20/98	51	8	9.0	66.5	6.17	13.1	7.7	22
ECO74B04	SQBANK	8/19/98	40	6	15.6	49.1	6.14	28.3	12.3	26
ECO74B04	SQBANK	4/14/99	43	8	18.9	58.9	5.41	15.7	8.6	28
ECO74B12	SQBANK	8/13/96	45	8	11.2	67.4	5.52	23.7	2.2	24
ECO74B12	SQBANK	4/27/97	41	14	55.7	29.3	4.95	13.8	38.9	42
ECO74B12	SQBANK	8/25/97	45	12	40.6	30.6	5.11	15.0	39.4	42
ECO74B12	SQBANK	4/27/98	39	16	68.0	15.1	4.51	23.8	50.6	42
ECO74B12	SQBANK	8/24/98	43	10	35.6	26.4	5.92	12.9	29.4	36
ECO74B12	SQBANK	4/19/99	49	14	33.8	42.5	6.06	14.5	22.7	36

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