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Developing a Multimetric Habitat Index for Wadeable Streams in Illinois

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(May 1, 2006 - December 31, 2009)

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Final Project Report 2010

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Developing a Multimetric Habitat Index for Wadeable Streams in Illinois

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Developing a multimetric habitat index for wadeable streams in Illinois

Introduction

In Illinois, several methods are used to collect and summarize habitat information in wadeable streams. Methods range from relatively rapid, subjective, visually-based surveys used by Illinois Department of Natural Resources (IDNR), to quantitative point-transect surveys used by Illinois Environmental Protection Agency (IEPA) and the Illinois Natural History Survey (INHS). The intensity of point-transect methods vary, but biologists often spend 1.5-2 hours per site collecting habitat data. Although these data provide a detailed description of stream conditions when sampling occurred, some features (e.g., wetted width) vary in response to seasonal conditions and weather events. Therefore, detecting meaningful changes in stream quality is difficult.

Another approach used by the IEPA is to use data collected through point-transect methods to measure biological potential, or the ability of a stream to support a healthy aquatic community where chemical and non-chemical stressors are not present (Barbour et al. 1997). Consequently, Hite and Bertrand (1989) developed the Predicted Index of Biotic Integrity (PIBI) by using multiple regression analysis that identified the stream habitat metrics most strongly related to biotic integrity as measured by the fish-based Index of Biotic Integrity (IBI; Karr et al. 1986). Although predicting the biotic potential of a stream is useful for determining causes of impairment (e.g., lack of habitat) and identifying sites with restoration potential, it does not facilitate comparisons among streams.

Frequently, qualitative habitat indices are used to rate a stream's physical environment (Stauffer and Goldstein 1997). These indices are less subjective than visually-based surveys and require less time and staff than point-transect methods. A measure employed in Illinois to ascertain stream habitat quality is the Stream Habitat Assessment Procedure (SHAP; IEPA 1994), a qualitative index comprised of 15 metrics. Illinois EPA developed SHAP to facilitate comparisons of stream quality across sites. To develop the index, qualitative habitat metrics were regressed against total IBI scores and individual IBI metrics and were ranked by R-square values (IEPA unpublished data, Marion office). Metrics that were highly correlated with IBI scores were selected for SHAP, and were subsequently assigned a scoring range that corresponded to their relative importance to fish communities. Although SHAP is a useful tool for comparing stream quality across sites, the metric scores are somewhat subjective and lack adjustment for natural variability throughout Illinois. Moreover, the metrics comprising SHAP may not provide clear signals of how streams respond to land use impacts on watersheds and streams.

Currently in Illinois, the Qualitative Habitat Evaluation Index (QHEI) is used to measure habitat features that generally correspond to the physical factors affecting fish communities and other aquatic life (Rankin 1989). As with SHAP, the QHEI metrics were selected because of strong correlation with stream fish communities (as measured by IBI) and not because of their response to human impacts. Although QHEI has less personal bias associated with scoring each metric, the index is based on a single set of scoring criteria that are applied statewide. Thus, regional differences that exist under natural conditions (i.e., conditions that are minimally impacted by humans) are not taken into consideration.

As Illinois' Wildlife Action Plan is implemented, there is a need for a habitat index that reflects improvements and deteriorations in aquatic systems. The main objective of this project was to develop a multi-metric habitat index for use in wadeable streams that was rapid to conduct, adjusted for regional differences that exist under natural conditions, and able to detect meaningful changes in a stream over time.

JOB 1. Rate sites for disturbance.

1.1 Investigate utility of using existing disturbance ratings developed by Smogor (2000).

Smogor (2000) used watershed measures of disturbance (i.e., proportion of undisturbed, disturbed, and strip-mined land; volume of impounded water and impounded industrial, mining and sewage waste water; and density of sewage and hazardous point sources) and site-specific measure of disturbance (e.g., stream-habitat condition, water and sediment chemistry measures) to rate community fish samples for degree of disturbance. Fish samples were identified as least, moderately or most disturbed and each potential IBI metric was examined for meaningful differences among these disturbance classes.

Project staff from the INHS discussed in detail existing disturbance ratings with Ann Holtrop (IDNR), Dr. Robert Fischer (Eastern Illinois University) and Roy Smogor (IEPA) and concluded that additional data were available at finer resolutions, which would allow for a significant improvement over the Smogor (2000) ratings. During the development of the Fish IBI, Smogor (2000) divided the state into approximately 800 watersheds. All sampling stations located within an individual watershed were assigned a common disturbance rating regardless of where disturbances were located within the watershed (e.g., upstream or downstream of the site). Currently, available data have allowed us to assess disturbance for much smaller watersheds (approximately 57,000 watersheds; Cordle et al. 2006) eliminating potential problems with downstream disturbances inappropriately being associated with upstream sites. Using some of the disturbance measures Smogor used to rate fish samples may not affect instream habitat similarly. Additionally, Smogor (2000) used site-specific measures of disturbance which were similar to features we planned to measure in this project. Therefore an alternative approach was developed to address these issues and to prevent circular reasoning.

1.2. Develop alternative disturbance rating scheme if needed.
Since human activities at different spatial scales may impact stream habitat we considered disturbance broadly using several potential measures that function at different scales. We attempted to parallel the measures used by Smogor (2000) but revised them to incorporate finer resolution data, eliminate disturbance measures that may not be applicable to a physical habitat index (e.g., NDPES Permit locations), and add any new measures that can now be attributed to stream reaches (e.g., density of road crossings).

Each potential measure was summarized at three spatial scales: (1) riparian zone (150 m buffer), (2) local watershed (area draining directly to the stream arc only, including the riparian zone), and (3) the total catchment (all upstream area, including the local watershed; Figure 3). Correlations between potential measures of disturbance summarized for the local watershed, total catchment and riparian zone were examined to determine if differences in scale were evident for each measure at individual stream reaches. The scale used for each disturbance measure was determined based on the level of the expected effect (e.g., road crossings would have local effects) and to minimize redundancy in use of the measures (e.g., disturbed land and undisturbed land are measured at different scales). Following our review, we selected five measures to include in the disturbance rating: (1) proportion of disturbed land in the total catchment, (2) maximum volume of impounded water in the total catchment, (3) proportion of strip-mined land in the local watershed, (4) proportion of undisturbed land in the riparian buffer, and (5) density of road crossings in the local watershed. A description of each selected disturbance measure and how it was scored follows.

1.2.a. Identify alternative measures of disturbance
Proportion of disturbed land
Disturbances from land use practices have been implicated as the cause of excessive stream habitat degradation including, but not limited to soil erosion and sedimentation (Roth et al. 1996). Other studies as well have indicated that measurement of land use disturbances is most appropriate at the catchment scale due to potential downstream impacts that poor land use practices may have on stream habitat (Allan et al. 1997, Lammert and Allan 1999, Roth et al. 1996). We chose to account for these processes using disturbed land in the total catchment. Proportion of disturbed land in the total catchment was calculated using land cover data from the Critical Trends Assessment Land Cover Database of Illinois (Luman and Joselyn 1996). Each stream arc (i.e., confluence to confluence section) statewide has been attributed with land cover type in the riparian zone, local watershed, and total catchment as part of a previous project (Cordle et al. 2006; Figure 1). Disturbed land uses (i.e., agricultural, urban and barren land delineations (cover types: agricultural = types 8, 9, 10; urban = types 1, 3, 4, 11; barren = type 23; Table 1) for the total catchment. Since these data were relatively normally distributed, the data were standardized into 20 equal scores (range 1-20; Figure 2).

Maximum volume of impounded water

Damming the natural flow of a stream not only reduces flow volume of a stream, but can also starve the water downstream of the impoundment of its natural sediment load. To restore this loss, the water will erode new materials from the stream banks or stream substrate. Volume of impounded water was measured within the entire upstream catchment to provide insight into the magnitude of the impact. Maximum storage-volume of impounded water (industrial, mining, or sewage-waste water) was calculated from the National Inventory of Dams 1995 and the Illinois Water Survey Dams Database 1997. We summed the volume of water upstream of each stream arc and attributed this volume to the arc. The volume of impounded water was divided by the area of the entire upstream catchment for a proportional measurement of impounded water (x 1,000 cubic m / square km). These data were highly skewed with many sites having no impounded water and a few sites had very large volumes of impounded water, therefore sites with no impounded water were assigned a score of 1, and sites with large amounts of water (upper 90th percentile) were assigned a score of 20. The remaining sites were standardized into 18 equal scores (range 2-19; Figure 3)

Proportion of strip-mined land

Strip-mining can have negative impacts on stream habitat, particularly associated with accumulation of fine sediments in runoff from mining sites. Strip-mined land was measured at the local watershed scale because the direct effects of strip-mining (e.g., increased runoff and sedimentation) would be most noticeable near the source. Proportion of strip-mined land (active post 1949) in the local watershed was determined using the total area of strip-mined land divided by the local watershed area (Figure 4). The distribution of proportions was highly skewed toward sites without mining impacts; therefore sites with zero mining in the local watershed were assigned a score of 1. The remaining proportions were standardized to 19 equal scores (range 2-20; Figure 5).

Proportion of undisturbed land

Disturbance in the riparian zone has been demonstrated to have systemic effects (e.g., changes in the hydrograph) on stream networks that can be observed locally as channel erosion and decreased bank stability. However, the positive effects of riparian protection are not likely to extend far beyond the area protected. Undisturbed land in the riparian buffer best represents the natural landscape associated with local habitat characteristics and channel development. Intact riparian zones can mitigate some of the systematic effects of watershed disturbance. Therefore we measured the proportion of undisturbed land at the riparian scale to account for local improvements in stream habitat associated with these conditions.

Land cover summaries for undisturbed land were available from previous work (Cordle et al. 2006) based on Luman and Joselyn (1996). The proportion of undisturbed land in the riparian zone was calculated using spatial data from the Critical Trends Assessment Land Cover Database of Illinois (cover types: upland forest = types 13, 14, 15; bottom land forest = types 20, 21; wetland = types 18, 19; Luman and Joselyn 1996; Table 1). These data were relatively normally distributed, therefore the data were standardized into 20 equal scores (range 1-20; Figure 6)

Density of road crossings

Road crossings influence instream habitat by providing a direct conduit for runoff and sediment transport and potentially altering the path of the channel. Due to the localized nature of these impacts, the density of road crossings was measured at the local watershed scale (Tiemann 2004, Hedrick et al. 2009). Density of road crossings was calculated by summing road-stream intersections and dividing by local watershed area (road crossings/km^2). The data were skewed with a few watersheds having very high road crossing density, therefore the upper 90th percentile was given a score of 20 and the remaining data were standardized into 19 equal scores (range 1-19; Figure 7).

1.2.b. Development of a Total Disturbance Score

The five disturbance-measure scores were summed to yield a total disturbance score for every stream arc (range 5-100). Total disturbance scores for all stream arcs in the state were plotted and natural breaks in the data were used to delineate least, moderately and most disturbed classes. Least disturbed sites comprised the lower 15th percentile range of the total disturbance scores, and most disturbed sites comprised the upper 90th percentile (Figure 8). Potential sampling sites were assigned the disturbance class of the stream arc on which each was located (Figure 9).

1.3. Select sites with range of disturbance for sampling

Sites were not selected to be statistically representative of Illinois streams (i.e., at random) but were selected to provide an adequate coverage of least, moderately and most disturbed streams within preliminary regions as well as to provide a statewide coverage of sample points. The regions chosen for the Fish IBI (Smogor 2000) were used to stratify the state to provide adequate coverage for other possible regionalization schemes. Thirty sites were chosen per IBI region to represent approximately similar gradients of disturbance within each for a total of 390 sites targeted. Potential sites were initially given priority if they were part of the IEPA/IDNR basin rotation, if they had fish IBI scores associated with them, or if other data were available or scheduled to be collected from that site.

During the months of May–September, each site was visited and assessed for potential to sample. If a site met the criteria for sampling (i.e., accessible, wadeable, and not intermittent) it was sampled at that time. If a site did not meet the criteria (i.e., was not wadeable or was intermittent), a decision was made as to whether or not the site should be revisited at a later date. If it was decided that the site was simply too small or too large to sample, it was discarded as a sampling point and was not revisited. Additional sites were chosen as needed to fill in gaps in the data coverage. Overall, 514 sites were sampled (Table 2).

JOB 2. Identify potential metrics.

2.1. Identify a list of candidate metrics by reviewing existing indices and the literature.

Potential habitat features were chosen by reviewing primarily SHAP (IEPA 1994; Table 3) and the QHEI (Rankin 1989; Table 4) because these are the qualitative indexes that have been or are currently being used by state agencies in Illinois. Other features were added based on discussions with the project team (e.g., use of features identified in Platts et al. 1983, Schumm 1960; see Appendix A). Because these methods contain metrics that are aggregates of in-stream habitat measures, we developed sampling protocols that would allow combining measurements in a variety of ways.

2.2. Develop sampling techniques for each candidate metric.

Sampling techniques were discussed at length with our collaborators from Eastern Illinois University and procedures were developed to facilitate data collection (Appendix B). Methods were fine-tuned during the 2006 field season. Habitat features were sampled at the whole reach and channel unit scales (Table 5). Definitions for substrate type (Table 6) and in-stream cover (Table 7) were based on existing methods (IEPA 1994).

At each stream sample site, a reach was defined as 20 times the mean stream wetted width with a minimum of 100 m and a maximum of 300 m plus the distance needed to reach the end of the final channel unit. When the final channel unit had no observable endpoint (e.g., a straight channelized ditch) the reach was defined as the shorter distance of 20 times the mean width or 300 m. We began each reach a minimum of 10 m upstream of an access point (most often a bridge or crossing) in order to minimize any effects of the access point (i.e., bridge effects). If the upstream side of the access point was inaccessible, or if state biologists routinely sample downstream of the access point, then the habitat was also sampled on the downstream side. Sampling was conducted by walking the length of the reach first to obtain an overall impression of the reach, then data were collected and a map was drawn of the reach as the samplers walked back to the access point.

At the reach scale, data were collected to describe the buffer and stream bank quality and stability, predominant channel unit type, substrate dominance, flow and depth variability, channel development and modifications, and average wetted width (Table 5; Appendix B). Predominant channel type for the reach was described as pool, riffle, or run. Dominance at the reach scale was estimated as the proportion of total reach length and not the number of channel units of a given type. For example, it was possible to have only one of five channels units defined as a pool, yet the predominant channel type could be "pool" if the majority of the reach was encompassed in this pool.

The buffer zone was assessed from the top of stream bank to 100 m away from the stream channel. The stream bank (i.e., the top of the water to the top of the bank) was assessed separately and not considered part of the buffer zone. The width of the buffer was visually estimated for each side of the stream and placed within one of six categories: none, very narrow, narrow, moderate, wide and very wide (Table 7). Acceptable cover within a buffer zone included trees, grasses, un-manicured shrubbery, and bare areas (if naturally bare, for example, due to recent flooding or bedrock). Grasses that were coarsely mowed between a stream and an agricultural field were considered buffer, but mowed grass as in a manicured lawn was not. Grazed pastures were considered agriculture and not counted as buffer. Dominant type of vegetation in the buffer was categorized as trees, woody/shrub, or herbaceous. If the vegetation within the buffer area did not have a dominant cover, but rather a mix of trees, woody and/or herbaceous material, “mixed” was marked as the cover type.

Bank cover was categorized separately for left and right stream banks. Categories of stream bank cover types were assessed as herbaceous vegetation, woody/shrub vegetation, trees, bare earth, and bedrock. The amount of stream bank covered by each category was estimated as none, sparse, intermediate or abundant. In addition to categorizing the types of cover on the stream bank, the amount of stream surface receiving sunlight between 10:00 am and 4:00 pm was estimated. The degree of shading was recorded as: water surface completely shaded; water mostly shaded with some sunlight; half water surface shaded, half full sunlight; most water surface receiving sunlight; lack of canopy, full sunlight reaching water.

Substrate was estimated at both the reach and channel unit scales. The dominant and subdominant substrate types for the reach and for each channel unit were visually estimated and recorded as boulder, slab boulder, cobble, gravel, fine gravel, sand, hardpan, silt or bedrock (Table 6). We used substrate types and size categories defined in the IEPA Quality Assurance and Field Methods Manual, Section E (IEPA 1994).

Flow was visually estimated as fast, moderate, slow, or no detectable flow for the entire reach and within each channel unit. While relative current velocities are somewhat dependent of stream type (i.e., fast flow in Illinois streams may be considered moderate flow in a higher gradient stream); these categories capture the general velocity of the water within the respective streams.

Ten depths were measured throughout each reach at approximately equal intervals. These depths generally followed the maximum depth within the channel units (i.e., thalweg) and essentially followed the bulk of the flow.

The concept of channel evolution was defined by Schumm et al. (1984) as the pattern of adjustment by a channel in response to human perturbations (e.g., increasing runoff, channelization, dredging, and mining). Channel evolution was assessed based on the descriptions of Schumm et al. (1984) as stable, incising, widening, stabilizing or stable (successional).

Each channel unit was identified as a mid-channel pool, lateral pool, run, riffle or transitional area. Mid-channel pools were defined as an area within the stream channel with little to no flow, in these units, sediment accumulation is expected during base flow and the thalweg is generally in the middle of the wetted width. Lateral pools were defined as areas with little or no flow and the thalweg distinctively skewed to one side of the wetted width at normal base flow. Runs are defined as areas with slow to fast flow, with depths generally deeper than riffles but shallower that pools. Riffles were sampled where the water depth and/or gradient of the stream made the surface of the water break into ripples. Flow in riffles was most often moderate to fast. Transitional areas were areas of a reach that were difficult to define due to mixed attributes. For example, an area that is shallow with little to no flow (therefore not a riffle, but to shallow to be a run or pool) may be defined as a transitional area because the unit did not definitively fall into one channel unit category.

Each channel unit was evaluated. Substrate dominance and flow were recorded in each channel unit as described previously. Maximum depth was recorded for every channel unit and eight depths were measured along a cross-section of the deepest portion of each pool.

In-stream cover was estimated within each channel unit (Table 8). Cover was only assessed if it was at or below the current water level. For example, a root wad was not included in the amount of cover in this category if it was exposed on the stream bank. Eight categories of cover were assessed: aquatic macrophytes, undercut bank, overhanging vegetation, root wads, root mats, boulders, logs or woody debris, aggregate large woody debris (LWD). Amount of cover in each category was estimated as none, sparse, intermediate or abundant. Overhanging vegetation was only considered as cover if it was within 1 m from the water surface. Abundance of individual logs or woody debris was estimated separately from aggregate LWD because each can function as different habitat. For example, inputs of small debris and individual logs provides the food base for macroinvertebrates and other microorganisms while aggregates of logs can provide cover and protection from flow for fishes and invertebrates. For any other cover found, the amount was assessed as “other” and the type was written down.

Embeddedness is a measure of how constrained larger substrates are by smaller particles; therefore it was not assessed for channel units in which substrate smaller than fine gravel was dominant. Embeddedness was recorded as: not embedded, 0-25%, 25-50%, 50-75% or 75-100% embedded. Because deposition is expected in pools at low flows, embeddedness was not assessed in mid-channel or lateral pools.

The depth of fines (i.e., sand, silt or clay) was measured within each channel unit where fines were not the dominate substrate type to account for unexpected deposition of sediment in the reach. In an undisturbed stream, fines would be expected to only accumulate in areas of locally reduced flow such as protected areas in macrophyte beds. Aggradation of fines in other areas can be a sign that excessive erosion is occurring within or upstream of the reach.

Because summer field crews consisted of students, graduate assistants, and professional staff, effective training was necessary to ensure consistent data collection. Crew members were trained on how to use the field sheets and definitions of categories. Then a stream was visited, at which attributes of the stream habitat and development were discussed to calibrate scoring techniques.

2.3. Sample metrics at chosen sample sites.
Following the development of sampling methods, data were collected at a total of 514 sites during the field seasons of 2006-2009 (Figure 9). Within some regions, it was not possible to select 10 least or most disturbed sites due to the lack of available streams with these disturbance ratings. Therefore once all targeted sites had been visited, we sampled additional stream arcs with appropriate disturbance classes until 10 or all accessible arcs were sampled in that region/disturbance class. Even with this extensive effort, certain regions had fewer than ten sites sampled within each disturbance class (Table 2).

Sampled stream sites ranged in size from link number 1-410 (Shreve 1967) and channel order 1-5 (Strahler 1957). Drainage areas (entire upstream catchments) ranged from 0.58-2260 km^2. Regional disturbance levels varied somewhat throughout the state. Streams in the northwest and southernmost portions of the state were relatively undisturbed while streams in the central area of the state were highly impacted by agriculture and in the northeast portion by urban landcover. Strip-mining was most prevalent in the south-central portion of the state.

Annual variation in water level was evident in streams sampled in multiple years. The summer of 2007 was extremely dry while the summers of 2008 and 2009 experienced high amounts of rainfall and consequently, flooding and channel alteration in many areas.

JOB 3. Determine regions

3.1. Identify possible regionalization schemes (e.g., watersheds, natural divisions).
Illinois is a large state encompassing areas that vary topographically, geologically, and historically. Therefore stream habitat and associated biotic assemblages may be expected to vary regionally. Moreover human impacts and habitat response in streams to those impacts can vary regionally (Smogor 2000), and a single set of metrics and metric-scoring criteria may not reflect land use disturbances equally well statewide. Regionalization of metric scoring can minimize the influence of natural variation in metrics on the overall index score ensuring that differences in index scores reflect human impacts. We investigated the relationship between habitat metrics and disturbance for several alternative regionalization schemes (Figure 10). These included natural divisions (Schwegman 1973), ecoregions (Woods et al. 2006), freshwater ecoregions (Abell et al. 2008), glacial boundaries, major watersheds, fish IBI regions (Smogor 2000), and a stream classification (Holtrop and Dolan 2003).

The fish IBI regions were developed by Smogor (2000) to account for regional variability in the composition of fish assemblages in least disturbed streams throughout the state (Figure 10a.). He considered fish samples in several alternative regional groupings (e.g., prior IBI regions, physiographic regions, major river basins, Illinois EPA's Aquatic Life Management Units) to chose a set of regions in which metrics varied maximally, therefore minimizing the potential for natural differences in metrics among regions to confound interpretation of the IBI scores.

Freshwater ecoregions are constrained by watershed boundaries with delineation primarily based on freshwater fish distributions (Figure 10b.). In developing the freshwater ecoregions, Abell et al. (2008) used the best available regional information describing freshwater biogeography, including influences of phylogenetic history, paleogeography, and ecology.

Ecoregions are based on general similarity of ecosystems and were developed to be used for implementation of ecosystem management across political boundaries (Figure 10c.; Woods et al. 2006). Ecoregions are based on a hierarchal scale designed to "… stratify the environment according to its probable response to disturbance, and recognize the spatial differences in the capacities and potentials of ecosystems (Bryce et al. 1999)." Illinois contains six level III ecoregions based on physiography, natural vegetation, soil, surficial and bedrock geology, climate, land use and land cover, and regional biogeography.

Glaciation is one of the most significant geologic processes to shape the landscape in Illinois. Three major episodes have occurred in Illinois' history: the Wisconsin, Illinois and the Pre-Illinois episodes. Glacial erosion and deposition has changed the landscape of Illinois by filling river valleys, changing the course of rivers, and creating new landforms. Glacial boundaries represent the extent of glaciations from the major glacial episodes in Illinois (Figure 10d; Illinois State Geological Society 1998).

Natural Divisions were developed to set the ground work for development of the Illinois State Nature Preserves program (Figure 10e.). The fourteen natural divisions in Illinois are based on differences in topography, glacial history, bedrock, soils and distribution of flora and fauna (Schwegman 1973).

Major watersheds were delineated by the State Water Survey (Figure 10f; McConkey and Brown 2000). Watershed boundaries follow topographic highs and a watershed is often considered synonymous with a drainage basin or the land area that directly drains to a common water body.

Finally, the utility of a stream classification based on stream size and gradient was investigated (Holtrop and Dolan 2003; Table 9). Stream size was defined as channel link, and slope was defined as percent gradient (Cordle et al. 2006, Brenden et al. 2006).

3.2. Identify degree to which metrics sampled at least-disturbed sites differ among regions.

Multivariate Analysis of Variance (MANOVA) was used with selected candidate habitat metrics to aid in determining the appropriate regionalization or stratification method (Table 10). Box plots of the candidate metrics were used to determine which method more consistently improved the ability to distinguish disturbance class beyond the statewide pattern.

3.3. Select final regions.

Of the stratifications examined, ecoregions (Woods et al. 2006) and the stream classification showed the strongest relations between the potential metrics (MANOVA, Table 10). We selected ecoregions to regionalize metric scoring and incorporated size and gradient into the regional scoring (Table 11; Figure 11). This approach is similar to the development of other indexes used in Illinois (e.g., Smogor 2000).

Due to the limited area within Illinois, in several ecoregions we were not able to sample (or find) adequate numbers of sites in each disturbance class within these ecoregions (Table 11). For sites in the Mississippi Alluvial Plain and the Driftless Area we suggest using the statewide scoring criteria as well as any available regional scoring for the area.

JOB 4. Select final metrics.

4.1 Select final metrics based on those that reflect levels of disturbance in each region.

A total of 201 metrics were examined during the study ranging from direct measurements to aggregations of metrics similar to some used by SHAP and QHEI (Appendix A). Metrics considered addressed categories including: substrate type and quality, in-stream cover types and amounts, channel quality and stability, riparian quality, amount of erosion, pool and riffle quality, channel unit development, thalweg depth, and flow variability. Analysis of variance (ANOVA), simple regression, box plots, and correlation matrices were used to examine the differences in each metric among disturbance classes.

We used the following three criteria to narrow 201 metrics to 20. Metrics chosen showed:

1. Statewide differences between disturbance classes (ANOVA, $P \leq 0.05$).
2. Metric increases or decreases as expected from least- to moderately- to most-disturbed conditions (box plots and correlation analysis (); Figure 12).
3. Metric values that varied between disturbance classes, but not within the least disturbed class. (To determine this, we examined correlations between metric scores and disturbance scores for the full range of sites (requirement $P \leq 0.05$) and of those, we examined correlations between metric scores and disturbance scores (not classes) within just the least-disturbed sites (requirement $P>0.05$).

Twenty metrics that differed meaningfully among disturbance classes statewide were selected from the original 201 (Appendix A) for further examination within the ecoregions (Table 12). For each metric, data from the most disturbed class were compared to data from the least disturbed class. If the metric was expected to increase with increasing disturbance, the threshold was set at the 75^{th} percentile of the least disturbed data. The range of data from the most disturbed class was compared to this threshold and the proportion of the data that fell above the threshold was calculated. Likewise, if the metric was expected to decrease with increasing disturbance, the threshold was set at the 25^{th} percentile, and the proportion of most disturbed data falling below this threshold was calculated. The calculated proportions were then examined.

Metrics with a proportion closer to one provide better discrimination between least and most disturbed sites.

Additionally we made box plots of the least, moderate, and most disturbed data of the 20 candidate metrics by ecoregion. Several of the 20 metrics were similar in nature (e.g., Buffer-bare includes Average buffer), therefore we selected only one of similar metrics to limit redundancy and to avoid weighting stream attributes unintentionally. The final five metrics were chosen based on the box plots across all regions, ability to discriminate between least and most disturbed stream sites, and lastly, with consideration of sampling ease. The final metrics are: percent shade, buffer-bare, substrate ratio, large woody debris, and the proportion of channel units that were riffles (Table 12).

JOB 5. Develop scoring criteria for each region.

We developed statewide and regional scoring criteria for wadeable Illinois streams using the five metrics identified in Job 4. The full range of sites was treated as a single region for developing statewide scoring criteria and sites were grouped by ecoregion and used to develop regional scoring.

Potential outliers and influential data points were identified for each metric using three methods: standardized deleted residuals (>2), centered leverage values (>4/n), and DFBETA (change in regression coefficient resulting from the deletion of the i^{th} case; >2/sqrt n; SPSS 2008. Data that were identified as outliers by two of the three methods were removed from further analysis (of that metric in that ecoregion only). This occurred with less than 5% of data within each region.

Normal probability plots were examined for each candidate metric and three potential covariates. Link, width, gradient, the proportion of large woody debris and the substrate ratio were transformed with natural log. Buffer-bare, proportion of riffles and percent shade were relatively normal and therefore not transformed.

5.1. Establish regional scoring criteria for each metric.
Earlier analysis (Job 3; MANOVA) indicated that stream size and gradient explained some of the natural variation in several of our metrics. To address this within regions; scatter plots of each metric were examined for meaningful variation with stream size (link number, wetted width) and gradient using data from our least disturbed sites. The covariate (link number, wetted width, or gradient) with the strongest relation to the metric (highest R-squared value ≥ 0.10) was selected to assist with scoring the metric. When no strong relation was found the mean value of the metric based on the least disturbed data was used to set the scoring.

We plotted the regression line (or the mean value) of the metric against the covariate using the least disturbed site data. This formed the lower bound of the highest scoring class when the metric was negatively correlated with disturbance or the upper bound of the highest scoring class when the metric was positively correlated with disturbance (e.g., substrate ratio). We then divided the area between the metric boundary and the minimum value (or 90th percentile value for substrate ratio) into four equally spaced areas. The resolution of the data for percent shade only allowed separation into four meaningful classes so only three equally spaced areas were used.

We assigned a score of 5 to the area above the regression line of the least disturbed site data for buffer-bare, large woody debris, and proportion of riffles. Since shading had only four classes the area above the regression line was given a value of 4. The substrate ratio metric was given a value of 5 below the regression line since this metric was positively correlated with disturbance. We then sequentially decreased the value by one for each adjacent region for all metrics. For consistency on how the regional metric scoring is displayed those metrics that were not observed to be related to stream size or gradient were plotted as lines with zero slope against the natural log of gradient (Appendix C).

Metric values should be plotted on the appropriate regional, or statewide, scoring graph to obtain metric scores (Appendix C). The overall index value is then determined as the sum of individual metric scores and ranges from 5 – 24. Higher values indicate site conditions more similar to those of least disturbed sites within their region.

JOB 6. Prepare final report.

6.1. Prepare final report including a "how to" manual.
A training manual "Procedure for Physical Habitat Measurements and Scoring of the Illinois Habitat Index" was prepared and included with this final report (Appendix D).

6.2. Conduct a training workshop.
The training workshop was not conducted due to the index completion during winter. Personnel from the INHS working on the coolwater stream (T-13) and mussel communities (T-53) projects have been trained to collect data for use with the index during sampling efforts in 2010. The IDNR is prepared and willing to conduct training sessions for other interested groups.

Conclusions

We scored all sites that were visited during the study period that had the appropriate data available (Figure 13). Mean and median index values were highest for least disturbed sites (mean = 18.1, std dev = 3.2, median = 19.0, range 6 – 24, n = 146), and declined in moderately disturbed (mean = 16.0, std dev = 4.7, median = 16.5, range 5 – 24, n = 210), and most disturbed sites (mean = 15.3, std dev = 4.3, median = 15.0, range 5 – 24, n = 131). Sixty-four percent of moderately disturbed and seventy-five percent of most disturbed sites scored lower than the least disturbed sites median index value although the range of index values was relatively broad within each disturbance class. Sixty-one percent of the index scores for most disturbed sites were below the median index value of the moderately disturbed sites. These results suggest that the index has excellent discriminatory power for separating least disturbed sites from most disturbed sites, and reasonably good ability to differentiate moderately disturbed sites from least disturbed or from most disturbed conditions.

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Table 1. Land cover classes used for delineation of land cover types for analyses of disturbance in whole and local watersheds and local riparian zones (Luman and Joselyn 1996).

Category Name	Category Description
Urban and Built-Up Land	
1 - High Density	All or most of the surface cover is comprised of impervious material
2 - Med-High Density	Transitional between Medium and High Density; located in Cook County only
3 - Medium Density	Significant proportion of the surface cover is comprised of impervious material
4 - Low Density	Small amount of surface area comprised of impervious material mixed with other land cover
Transportation	
5 - Major Roadways	Major Highways updated 1992
6 - Active Railroads	Updated 1991
7 - Abandoned Railroads	Updated 1991
Crop Land	
8 - Row Crop	Corn, soybeans, and other tilled crops
9 - Small Grains	Wheat, oats, etc.
10 - Orchards/Nurseries	Cultivated tree crops
Grassland	
11 - Urban Grassland	Parks, residential lawns, golf courses, cemeteries, and other open space
12 - Rural Grassland	Pastureland, grassland, waterways, buffer strips, CRP
Wooded and Forested Land	
13 - Deciduous	Undifferentiated broadleaf deciduous, closed canopy
14 - Deciduous	Undifferentiated broadleaf deciduous, open canopy
15 - Coniferous	Undifferentiated
16 - Open Water	
17 - Perennial Streams	
Wetland	
18 - Shallow Marsh/Wet Meadow	No extra description given in the metadata
19 - Deep Marsh	No extra description given in the metadata
20 - Forested Wetlands	No extra description given in the metadata
21 - Swamp	No extra description given in the metadata
22 - Shallow Water Wetlands	No extra description given in the metadata
23 - Barren Land	quarries, sandy beaches, exposed soil surfaces, etc.

Table 2. Total number of sites sampled by IBI region and disturbance class.

IBI	Disturbance Class			
Region	Least	Moderate	Most	Total
1	7	9	9	25
2	12	18	10	40
3	10	12	10	32
4	9	15	10	34
5	7	15	11	33
6	7	32	11	50
7	14	22	18	54
8	13	16	12	41
9	14	24	8	46
10	14	8	16	38
11	14	28	9	51
12	20	16	5	41
13	11	13	5	29
Total	152	228	134	514

Table 3. Metrics and scores comprising Illinois' Stream Habitat Assessment Procedure (SHAP). The overall index value is determined as the sum of individual metric scores and ranges from 5 – 24. Higher values indicate site conditions more similar to those of least disturbed sites within their region.

Metric	Excellent	Good	Fair	Poor
Substrate and Instream Cover				
Bottom Substrate	16-20	11-15	6-10	1-5
Deposition	10-12	7-9	4-6	1-3
Substrate Stability	13-16	9-12	5-8	1-4
Instream Cover	10-12	7-9	4-6	1-3
Pool Substrate	16-20	11-15	6-10	1-5
Channel Morphology and Hydrology				
Pool Quality	13-16	9-12	5-8	1-4
Pool Variability	13-16	9-12	5-8	1-4
Channel Alteration	7-8	5-6	3-4	1-2
Channel Sinuosity	10-12	7-9	4-6	1-3
Width: Depth Ratio	13-16	9-12	5-8	1-4
Hydrologic Diversity	10-12	7-9	4-6	1-3
Riparian and Bank Features				
Canopy Cover	10-12	7-9	4-6	1-3
Bank Vegetation	13-16	9-12	5-8	1-4
Immediate Land Use	7-8	5-6	3-4	1-2
Flow-Related Refugia	10-12	7-9	4-6	1-3

Table 4. **Metric comprising Ohio's Qualitative Habitat Evaluation Index (QHEI; gradient omitted).**

Metrics	Scores
Channel Morphology	
Sinuosity	High (4), Moderate (3), Low (2), None (1)
Development	Excellent (7), Good (5), Fair (3), Poor (1)
Channelization	None (6), Recovered (4), Recovering (3), Recent (1)
Stability	High (3), Moderate (2), Low (1)
Riparian Zone and Bank Erosion	
Riparian Width	Wide (4), Moderate (3), Narrow (2), Very Narrow (1), None (0)
Floodplain Width	Forest/Swamp/Woods (3), Shrub/Old field (2), Residential/Park (1), Conservation tillage/Fenced pasture (1), Urban/Industrial (0), Open pasture/Row crops (0), Mining/Construction (0)
Bank Erosion	None/little (3), Moderate (2), Heavy/Severe (1)
Pool/Glide and Riffle Run Quality	
Maximum Depth of Pools	>1m (6), 0.7-1.0 m (4), 0.4-0.7 m (2), 0.2-0.4 m (1), <0.2 m (0)
Morphology	Pool width > riffle width (2), pool width = riffle width (1), pool width < riffle width (0)
Current Velocity	Eddies (1), Fast (1), Moderate (1), Slow (1), Torrential (-1), Interstitial (-1), Intermittent (-2_
Riffle/Run Depth	Max >50 cm (4), Max 10-50 cm (3), Max 5-10 cm (1), Max <5 cm (0)
Riffle/Run Substrate	Stable (2), Moderate to stable (1), Unstable (0)
Riffle/Run Embeddedness	None (2), Low (1), Moderate (0), Extensive (-1), No Riffle (0)
In-stream Cover	
Cover Type	Undercut bank (1), Overhanging vegetation (1), Shallows (1), Rootmats (1), Deep pools (2), Rootwads (1), Boulders (1), Oxbows (1), Aquatic macrophytes (1), Logs/woody debris (1)
Cover Amount	Extensive (1), Moderate (7), Sparse (3), Nearly absent (1)

Table 4. cont. Metric comprising Ohio's Qualitative Habitat Evaluation Index (QHEI; gradient omitted).

Metrics	Scores
Substrate	
Substrate Type	Boulder slabs (10), Boulders (9), Cobbles (8), Gravel (7), Sand (6), Silt (2), Muck (2), Hardpan (4), Bedrock (5), Detritus (3), Artificial (0)
Substrate Origin	Limestone (1), Tills (1), Wetlands (0), Hardpan (0), Sandstone (0), Riprap (0), Lacustrine (0), Shale (-1), Coal fines (-2)
Substrate Quality: Silt	Heavy (-2), Moderate (-1), Normal (0), Silt free (2)
Substrate Quality: Embeddedness	Extensive (-2), Moderate (-1), Normal (0), None (1)

Table 5. **Candidate metrics that were collected by field staff for metric development (Appendix B). Scale refers to whether the metric was recorded for each individual channel unit (e.g., run, riffle, pool, or transitional), for the entire sampling reach, or both.**

Metric	Definition	Scale
Buffer Width	Width of the undeveloped buffer on each side of the stream	Reach
Riparian Type	Type of vegetation growing in the buffer zone	Reach
Stream Bank Vegetation	Type of vegetation growing on the stream banks	Reach
Predominant Channel Type	Pool, Riffle, or Run	Reach
Predominant Substrate	Most abundant type of substrate (see Table 6)	Both
Predominant Flow	Fast, Moderate, Slow, or No detectable flow	Both
Shading of Water Surface	Completely, mostly, half, most light, all light	Reach
Thalweg Depths	10 approximately equidistant depths taken	Reach
Channel Evolution Stage	Per Schumm et al. (1984)	Reach
Water Level	Rising, base flow, decreasing or pooled	Reach
Stream Modifications	Any human perturbations are noted	Reach
Wetted Width	Taken at the downstream, mid and upstream points	Reach
Thalweg Depth	Taken at the downstream, mid and upstream points	Reach
Channel Unit Type	Lateral pool, mid-channel pool, riffle, run or transitional	Unit
Cover	Abundance of 9 cover types (see Table 3)	Unit
Substrate Embeddedness	Only applied to sites with dominant substrate as fine gravel and larger	Unit
Depth of Fines as Bottom Cover	Recorded as None, 1-25 mm, 25-50, 50-75, and >75 mm	Unit
Cross Section Depths	Eight depths are taken across pools from left to right bank facing upstream	Unit
Max depth	Deepest point of a unit (measured in all units)	Unit

Table 6. **Substrate and bottom type categories used in stream habitat assessment taken from Illinois' Stream Habitat Assessment Procedure (SHAP; IEPA 1994).**

Substrate type	Particle size
Bedrock	Solid rock
Hardpan	Compacted fines
Silt	<0.062 mm
Sand	0.062-2 mm
Fine Gravel	2-8 mm
Gravel	8-64 mm
Cobble	64-256 mm
Slab Boulder	>256 mm
Boulder	>256 mm

Table 7. Buffer categories used in stream habitat assessment.

Buffer Size	Width of Buffer
None	<1 m
Very Narrow	1-5 m
Narrow	5-10 m
Moderate	10-50 m
Wide	50-100 m
Very Wide	>100 m

Table 8. **Cover definitions for channel units. Amount of each cover type is estimated as none, sparse, intermediate or abundant.**

Cover Type	Definition
Aquatic macrophytes	Non-terrestrial, emergent, floating, or submerged macrophytes, not including algae
Undercut bank	Bank with a cavity below the waterline
Overhanging vegetation	Plant foliage suspended over the wetted channel and within one meter of the water's surface
Rootwads	Root mass from a tree that is in wetted channel and diverting water flow
Rootmats	Fibrous roots from trees and other plants extending into the wetted channel
Boulder	Substrate particle larger than 250 millimeters (modified Wentworth scale) along the second shortest axis
Large woody debris (LWD)	Woody material (e.g. log or tree) with a diameter greater than 10 cm, length greater than 1 meter, in wetted channel and diverting water flow
Aggregate of woody debris	Two or more LWD, must be in wetted channel and diverting water flow

Table 9. **Stream classes were determined by gradient and size. Gradient was measured as percent slope. Stream size was measured by link number. Table 9a provides the ranges for size and gradient with in each class. Every stream arc was given two numbers; one for the corresponding gradient group and one for size. These number were combined categorically (e.g., a stream a with link number 25 and a gradient of 0.0012 would be put in the 21 category for stream class). Table 9b provides the number of sites sampled in each disturbance class for each stream type.**

Table 9a.

Group	Description
Gradient	**Percent Slope**
1	0-0.001364
2	0.001365-0.003778
3	>0.003778
Size	**Link Number**
1	0-20
2	21-150
3	151-180
4	181-725
5	726-1300
6	1301-6500
7	>6500

Table 9b.

Stream Class	Least	Moderate	Most	Total
11	33	68	35	136
12	45	42	34	121
13	30	30	17	77
21	19	54	23	96
22	13	16	11	40
23	10	9	10	29
31	1	6	0	7
41	1	3	4	8
Total	152	228	134	514

Table 10. **Model significance results reported for the Multivariate Analysis of Variance (MANOVA) run on candidate regionalization schemes using potential index metrics. Numbers with a box around them and highlighted yellow (grey) indicate a significance level of $p \leq 0.05$. Dependent variables are defined in Appendix A.**

Dependent Variable	IBI Regions	Freshwater Ecoregions	Major Watersheds	Natural Divisions	Glacial Boundaries	Ecoregions	Size Gradient Class
Proportion of runs	.055	.895	.588	.205	.139	**.004**	.726
Proportion of riffles	.710	.748	.670	.543	.421	**.043**	.274
Average buffer width	.492	.313	.777	.507	.395	.310	.560
Average riparian type	.089	.195	.156	.064	.240	.241	.484
Buffer riparian	.232	.475	.603	.419	.317	**.023**	.696
Average Buffer Ranked	.754	.565	.554	.756	.439	**.037**	.114
Riparian QHEI	.100	.079	.767	**.756**	.309	**.011**	.779
Substrate stability	.399	.262	.243	.673	.253	.456	**.005**
Percent shade	.916	.830	.595	.503	.461	.578	.072
Thalweg max:min	.172	.390	.128	.287	.664	**.030**	.641
Thalweg mean:max	.834	.944	.281	.726	.283	.382	**.025**
Thalweg range	.278	.552	.497	.107	.375	.851	**.024**
Max Depth in Units	.695	.326	.875	.134	.607	.686	.440
Pool Quality	.265	.476	.513	.228	.202	.874	.058
Pool WOOD	.813	.722	.702	.295	.761	.985	**.000**
Count of cover	.800	.272	.401	.127	.219	.444	.155
Cover structure	.594	.666	.288	.551	.787	.390	.752
Proportion of aquatic macrophytes	.186	.141	.112	.924	.176	.153	**.000**
Proportion of LWD	.873	.599	.747	.693	.232	.103	**.000**
Proportion of WOOD	.458	.915	.550	.946	.463	.801	.226

Table 11. **Number of sites sampled in each disturbance class in each ecoregion.**

	Disturbance Class			
Ecoregion	Least	Moderate	Most	Total
Central Corn Belt Plains	33	107	63	203
Driftless Area	7	8	9	24
Interior Plateau	15	12	6	33
Interior River Valleys and Hills	86	94	53	233
Mississippi Alluvial Plain	1	1	1	3
Southeastern Wisconsin Till Plain	10	6	2	18
Total	152	228	134	514

Table 12. List of the final candidate metrics narrowed down from the original 200. The final five metrics used are listed first.

Metric Name	Metric Description
Percent shade	Shade recorded as a percentile category ranging from no shade to completely shaded [0-25-50-75-100]
Buffer / bare	Average of buffer minus average amount of bare soil on the banks + 3 (range 0-8)
Proportion of large woody debris cover	Proportion of logs and aggregate large woody debris in all units except riffles
Proportion of riffles	Proportion of units that are labeled as riffles in the reach
Ratio dominant next size	Of the dominant and next dominant substrate for the reach, ratio of the largest to the smallest (substrate sizes assigned from Table 6)
Pool wood	Sum of the sums of large woody debris + aggregate wood + rootwads for each pool divided by 3*number of pools in reach
Substrate stability	Sum of the proportions of boulder and cobble + aquatic macrophytes
Proportion of aquatic macrophytes	Proportions of aquatic macrophytes as cover in all units except riffles
Wood in pools	Proportion of logs, woody debris and root wads in all pools
Count of cover	Count of the number of cover types in the reach
Average buffer	Sum (left buffer width + right buffer width) divided by 2
Average riparian type	Coded riparian types averaged across the left and right banks.
Buffer riparian	Sum of coded (Average buffer width + Average riparian type)
Cover structure	Count of left and right values (trees + herbaceous + wood + bedrock) from the stream reach bank cover
Channel development	Sum (Average buffer + Average riparian + Channel evolution)
Proportion of runs	Proportion of units that are runs in the reach
Pool quality	An integrated measure based on pool type, depth, cover, and development. See Appendix C.
Max of max depth unit	The deepest maximum depth across all units
Thalweg max:min	Ratio of the largest to the smallest depths (max depth divided by min depth)
Thalweg mean:max	The average thalweg depth divided by the max thalweg depth
Thalweg range	The maximum thalweg depth minus the min thalweg depth

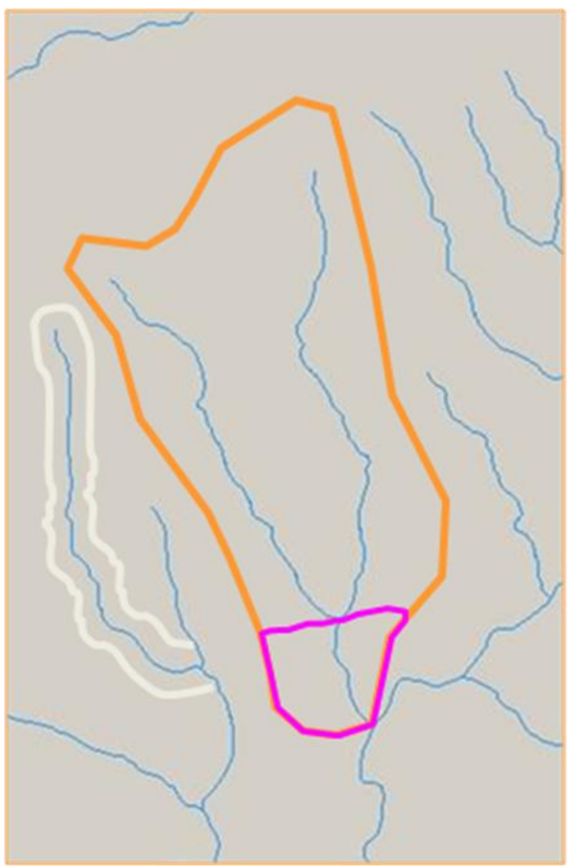


Figure 1. Sketch of a local watershed, total upstream catchment, and riparian zone. Local watersheds pertain to area draining directly to the specific stream arc, while the catchments include all upstream drainage area. Riparian zone included a 150 m buffer centered on the stream arc. The riparian zone did not extend up into the total catchment.

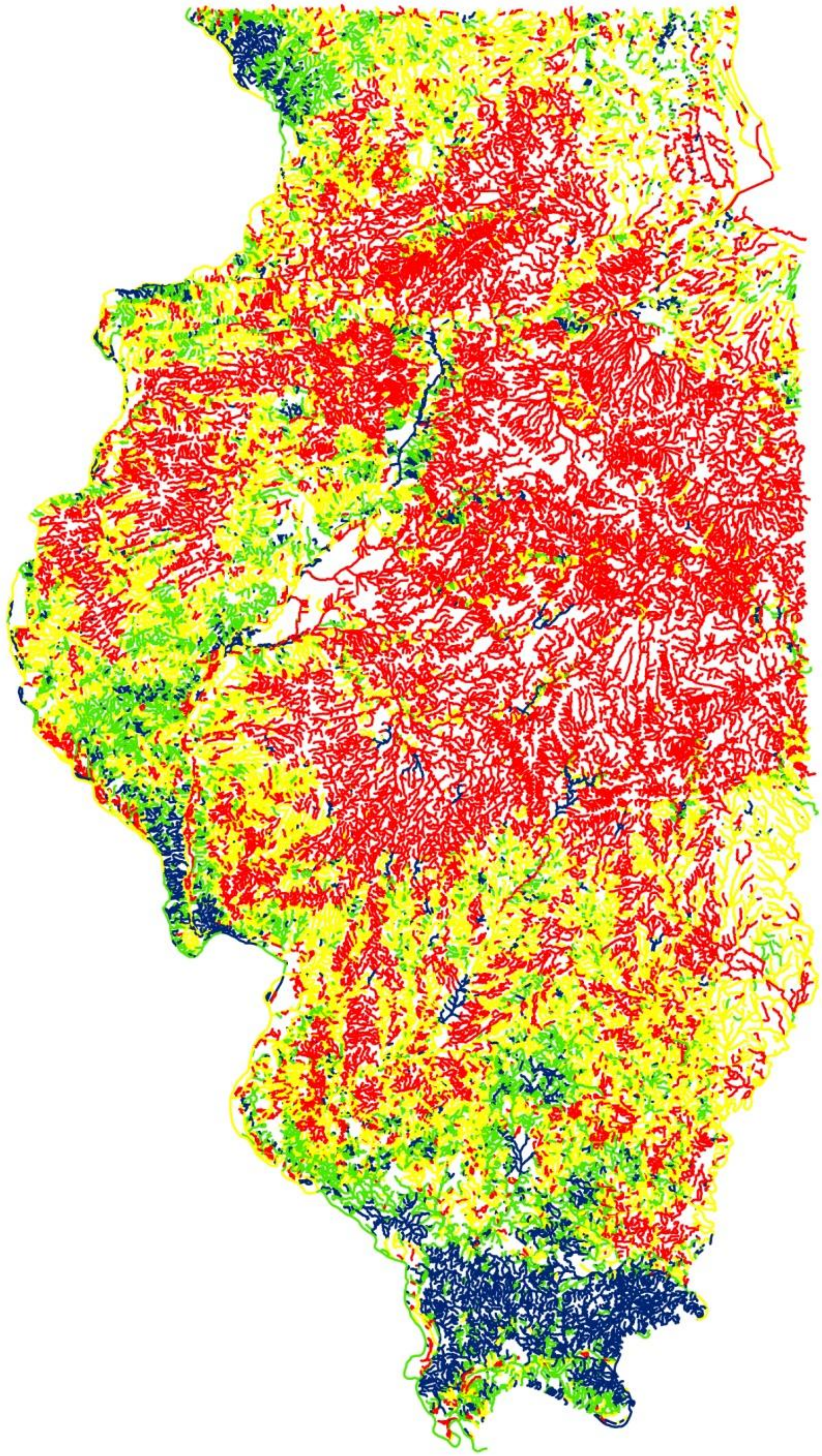


Figure 2. Distribution map of disturbance ratings for proportions of disturbed land in the whole watersheds of Illinois streams. Stream arcs are color coded by disturbance rating: 1-5 = blue, 6-10 = green, 11-15 = yellow, 16-20 = red. Smaller numbers ratings indicate less disturbance of this type.

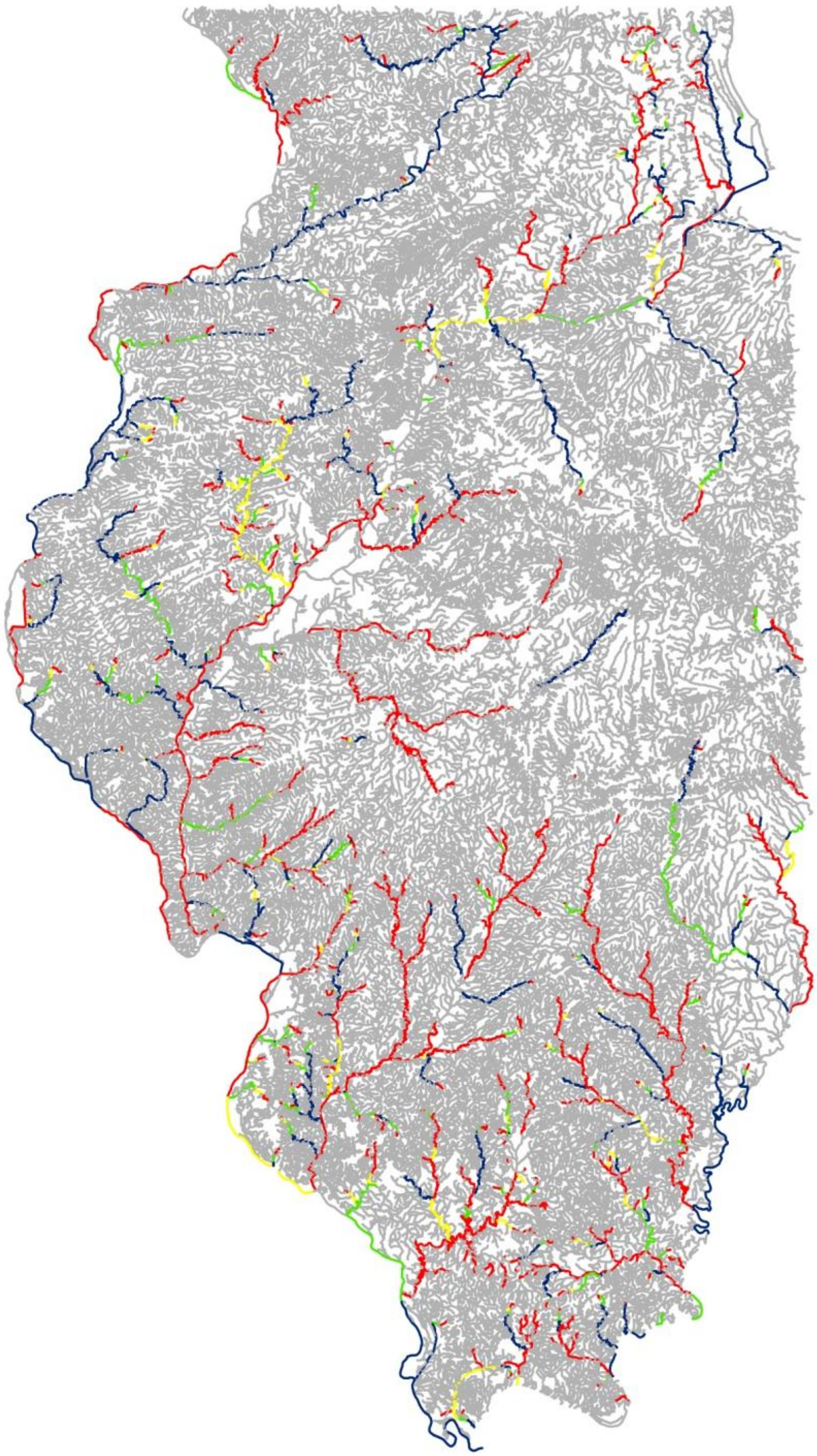


Figure 3. Distribution map of disturbance ratings for the volume of impounded water in the whole watershed of each stream arc. Stream arcs are color coded by disturbance rating: 1 = grey, 2-5 = blue, 6-10 = green, 11-15 = yellow, 16-20 = red. Smaller numbers ratings indicate less disturbance of this type.

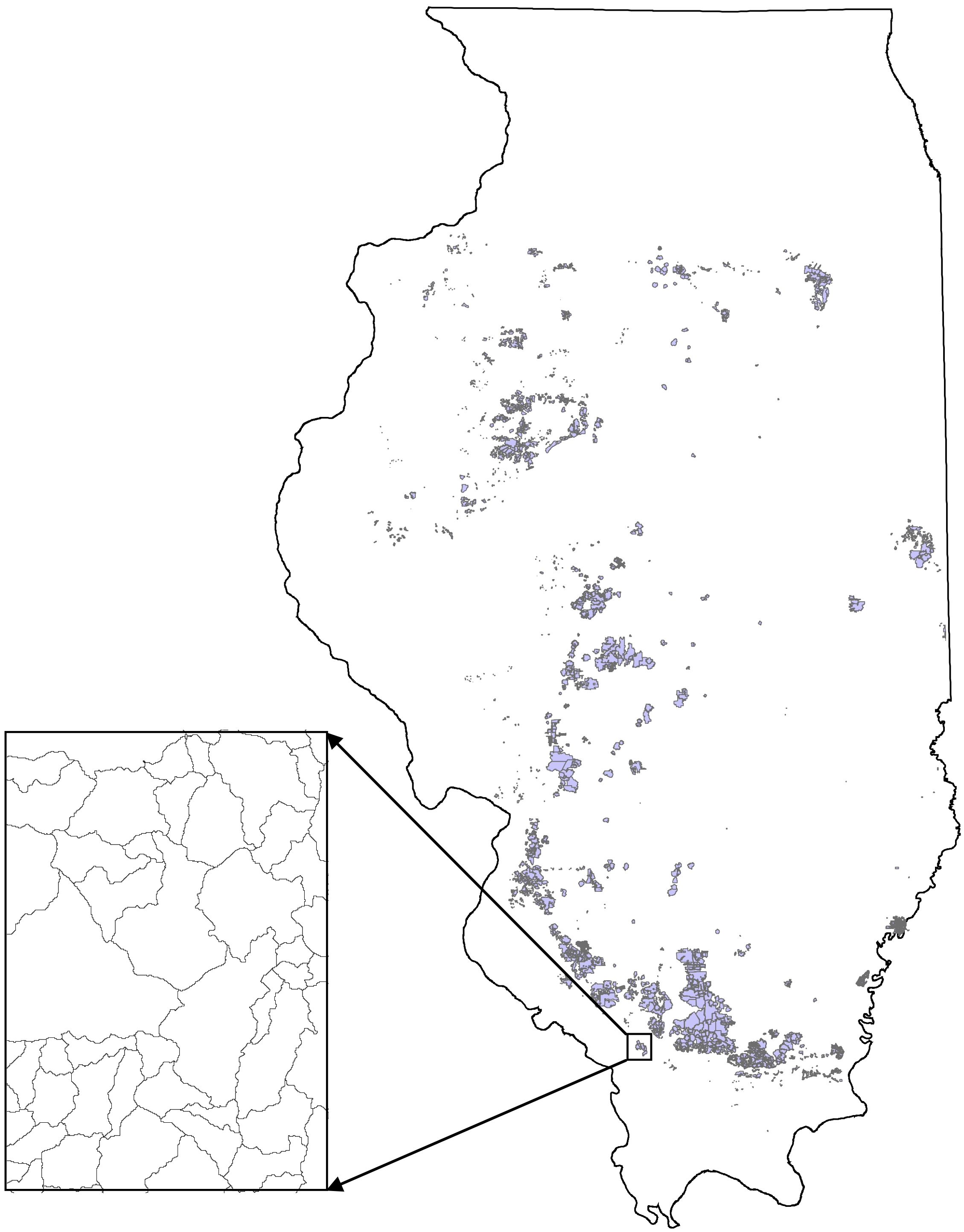


Figure 4. A map showing an example of the proportion of strip-mined land (gray) in each watershed assessed (black outlines in the inset). Proportions were calculated by dividing the area of each watershed in strip-mined land by the total area of that watershed. Proportions were used to determine disturbance classes for each disturbance type (Figure 5).

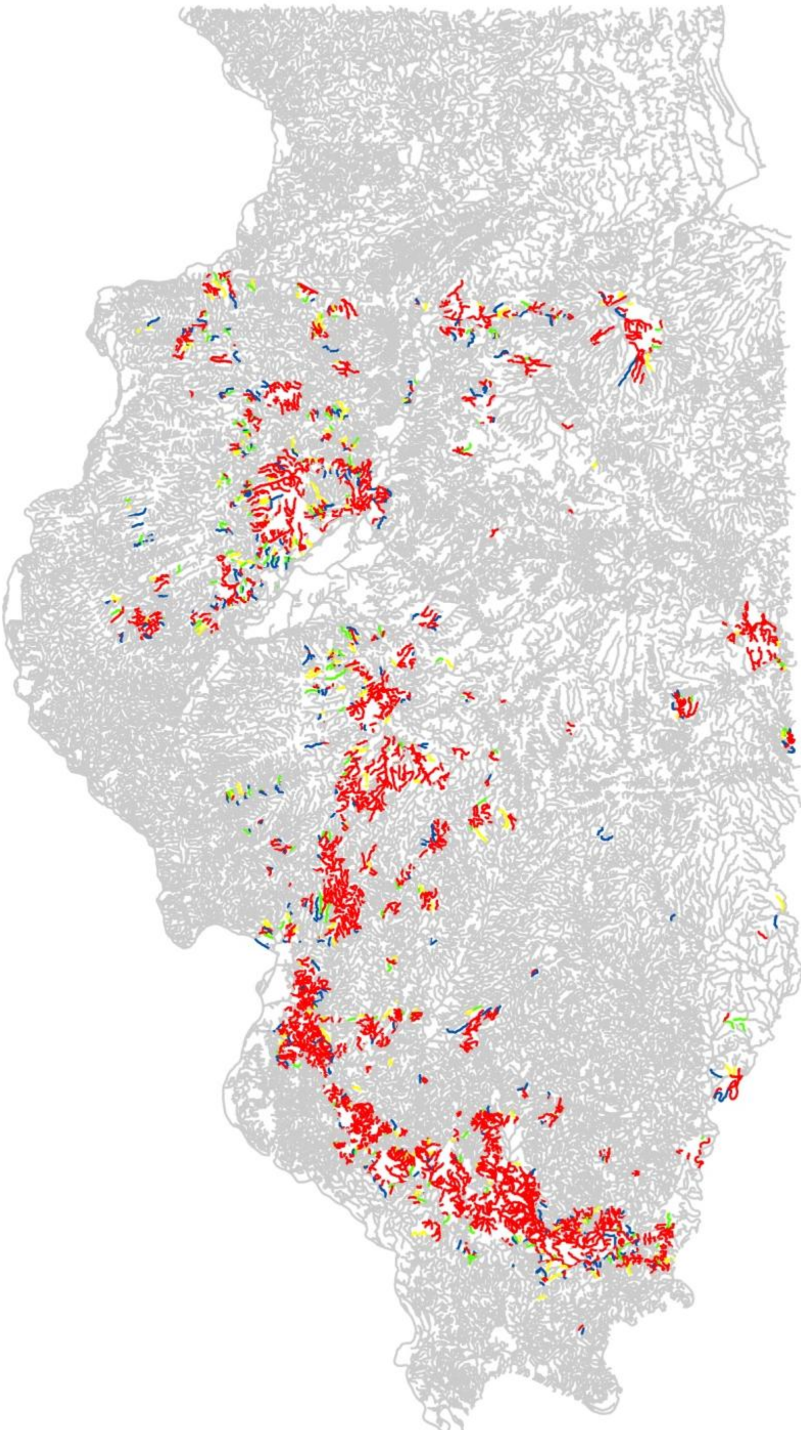


Figure 5. Distribution map of disturbance ratings for strip-mined land affecting Illinois streams. Stream arcs are color coded by disturbance rating: 1 = grey, 2-5 = blue, 6-10 = green, 11-15 = yellow, 16-20 = red. Smaller numbers ratings indicate less disturbance of this type.

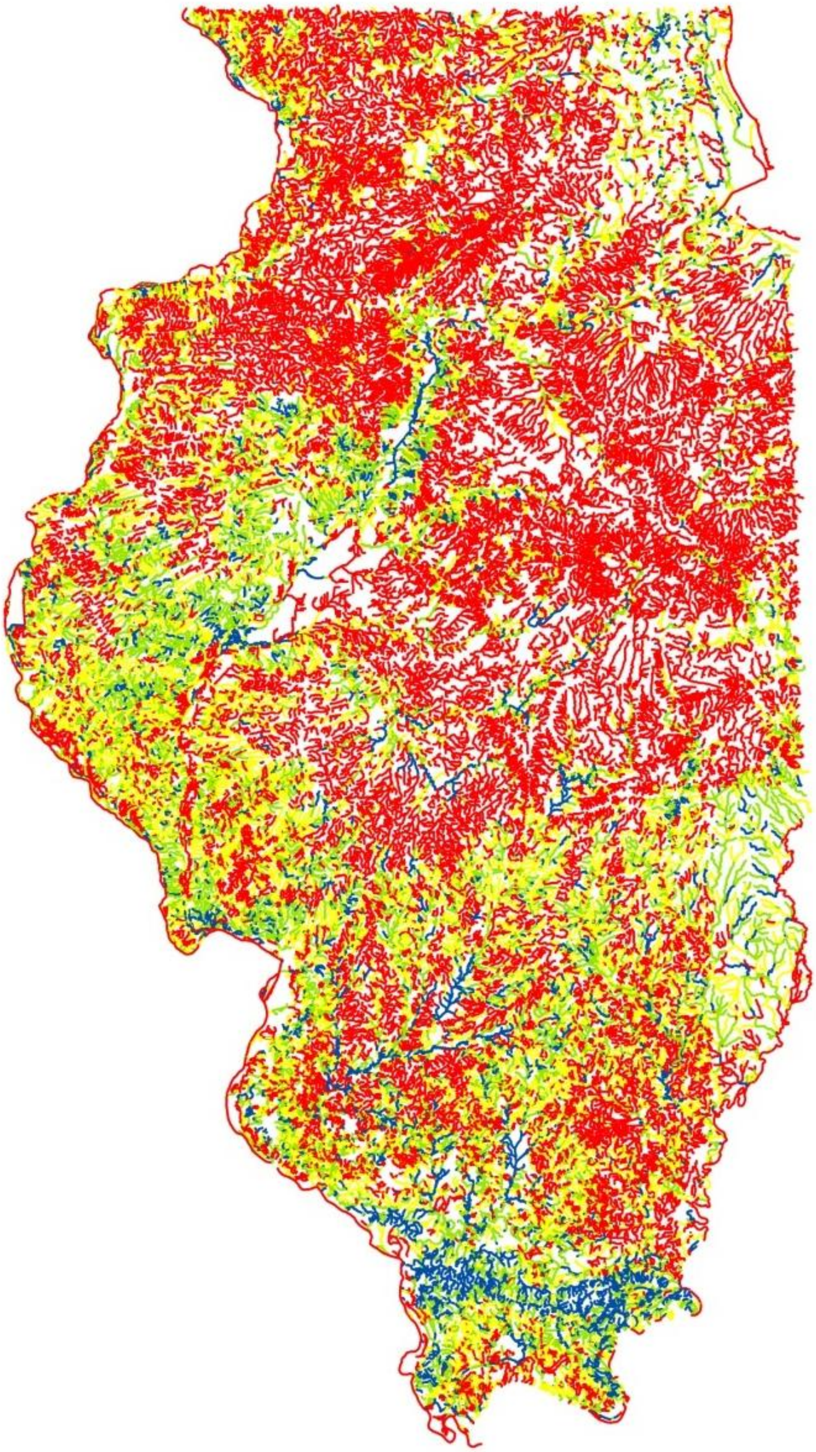


Figure 6. Distribution map of disturbance ratings for undisturbed land uses in the riparian zones of Illinois streams. Stream arcs are color coded by disturbance rating: 1-5 = blue, 6-10 = green, 11-15 = yellow, 16-20 = red. Smaller numbers ratings indicate less disturbance of this type.

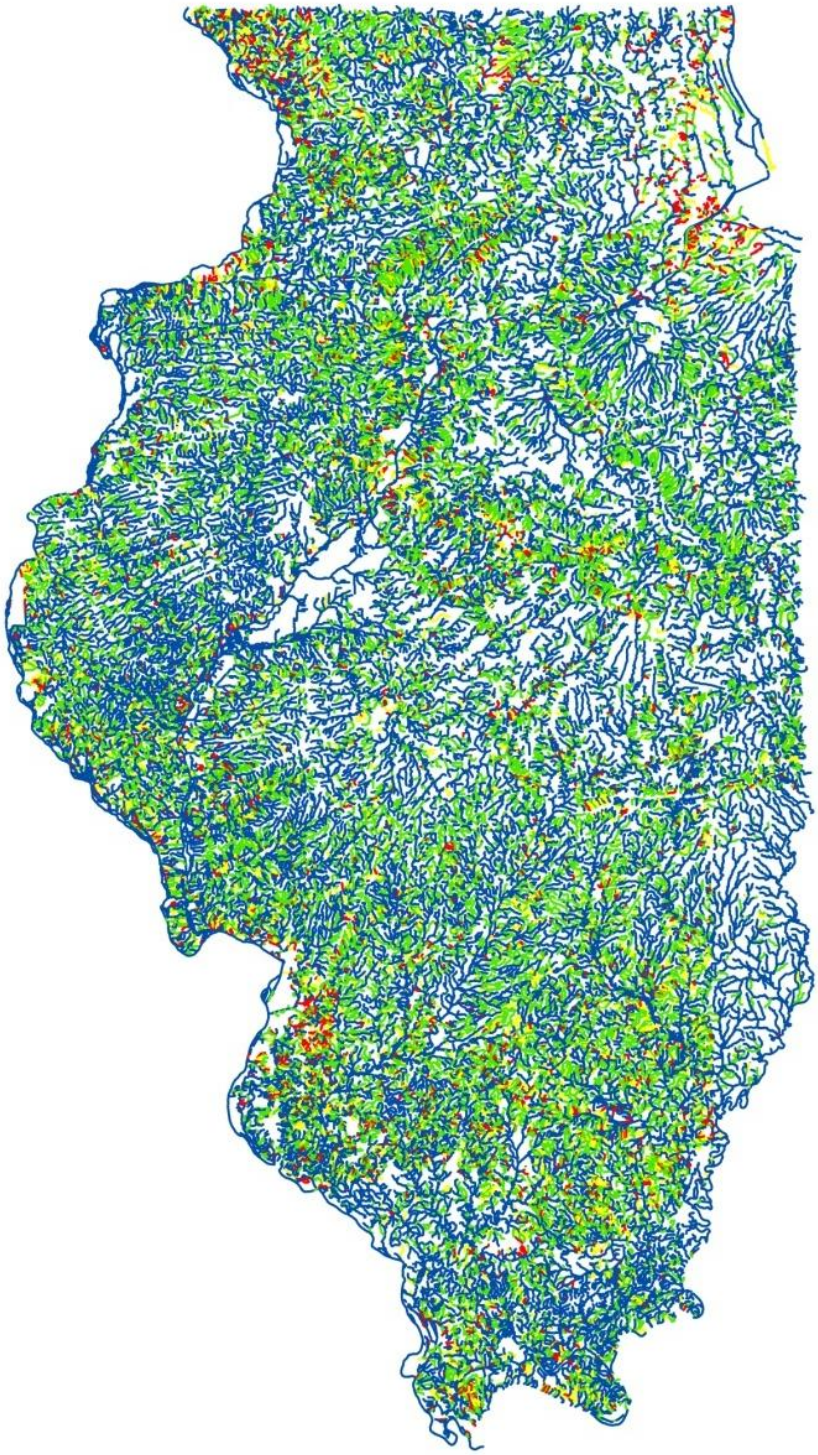


Figure 7. Distribution map of disturbance ratings for the density of road crossing in the local watershed for Illinois streams. Stream arcs are color coded by disturbance rating: 1-5 = blue, 6-10 = green, 11-15 = yellow, 16-20 = red. Smaller numbers ratings indicate less disturbance of this type.

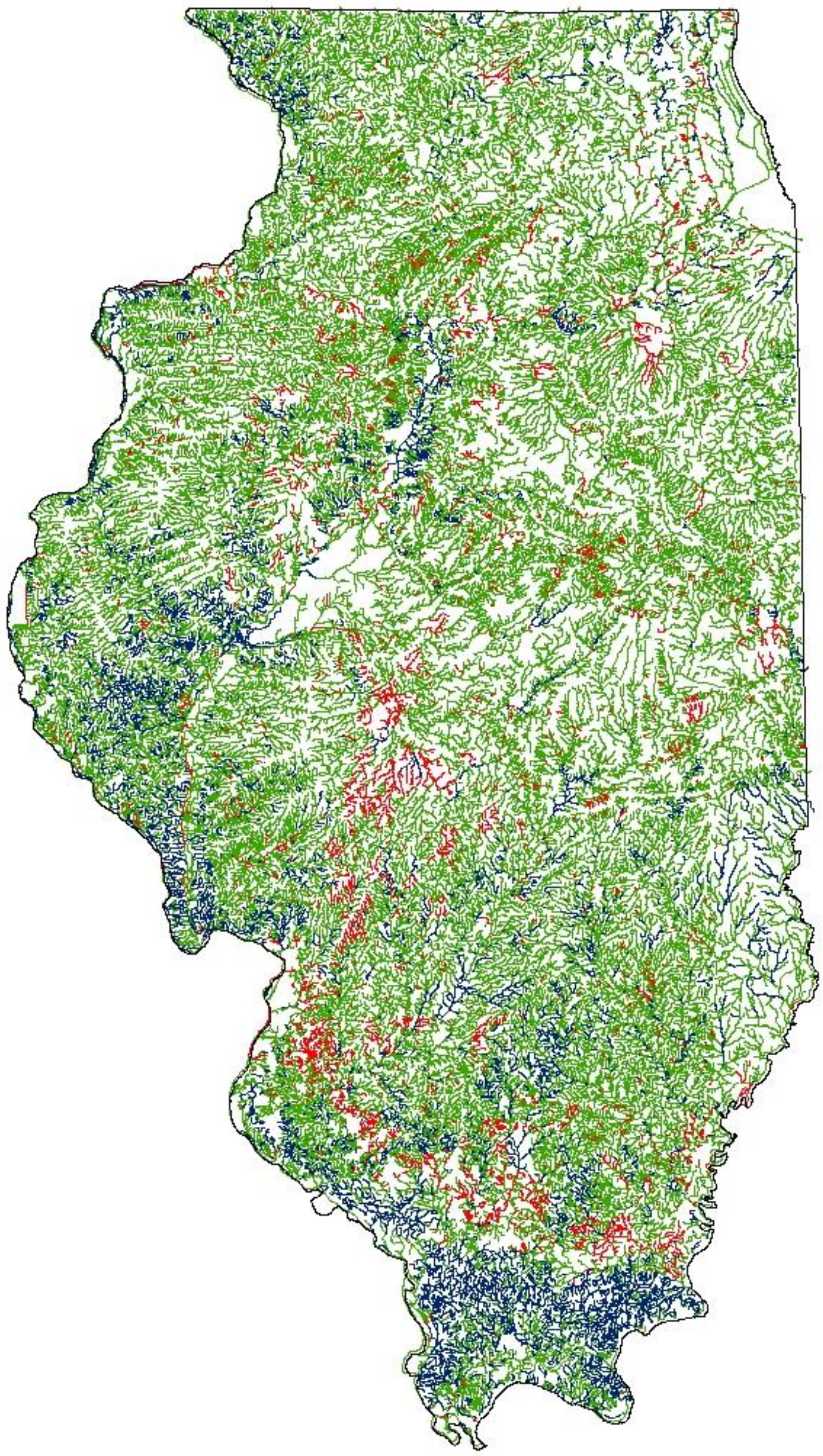


Figure 8. Map depicting total disturbance classes for stream arcs in Illinois. Blue streams are least disturbed (lower 15th percentile), green are moderately disturbed and red streams are most disturbed (upper 90th percentile).

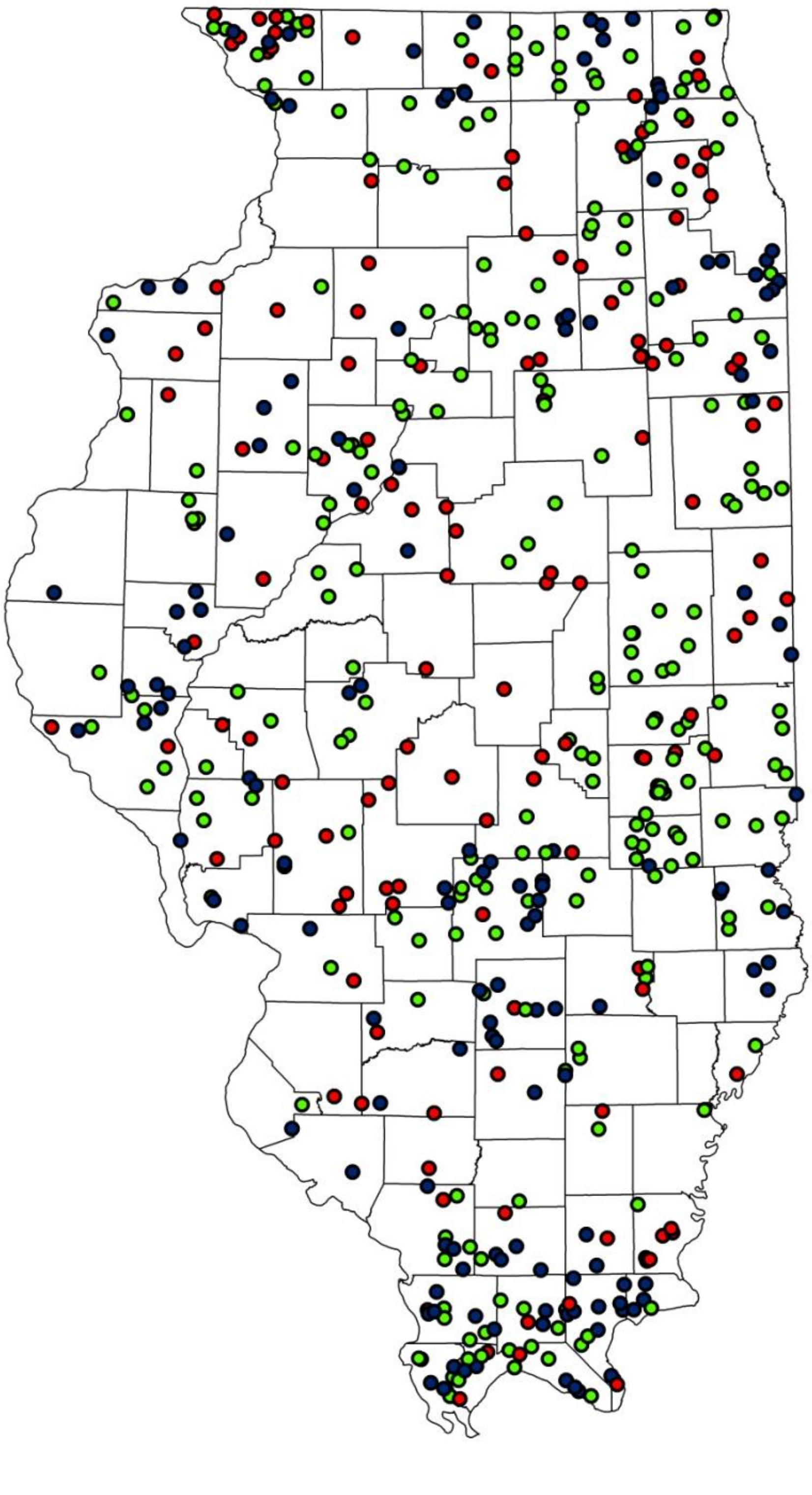


Figure 9. Map of Illinois showing the location of all sampled sites. Blue circles represent sample locations on streams that are least disturbed, green are moderately disturbed and red circles are sample locations on most disturbed stream arcs.

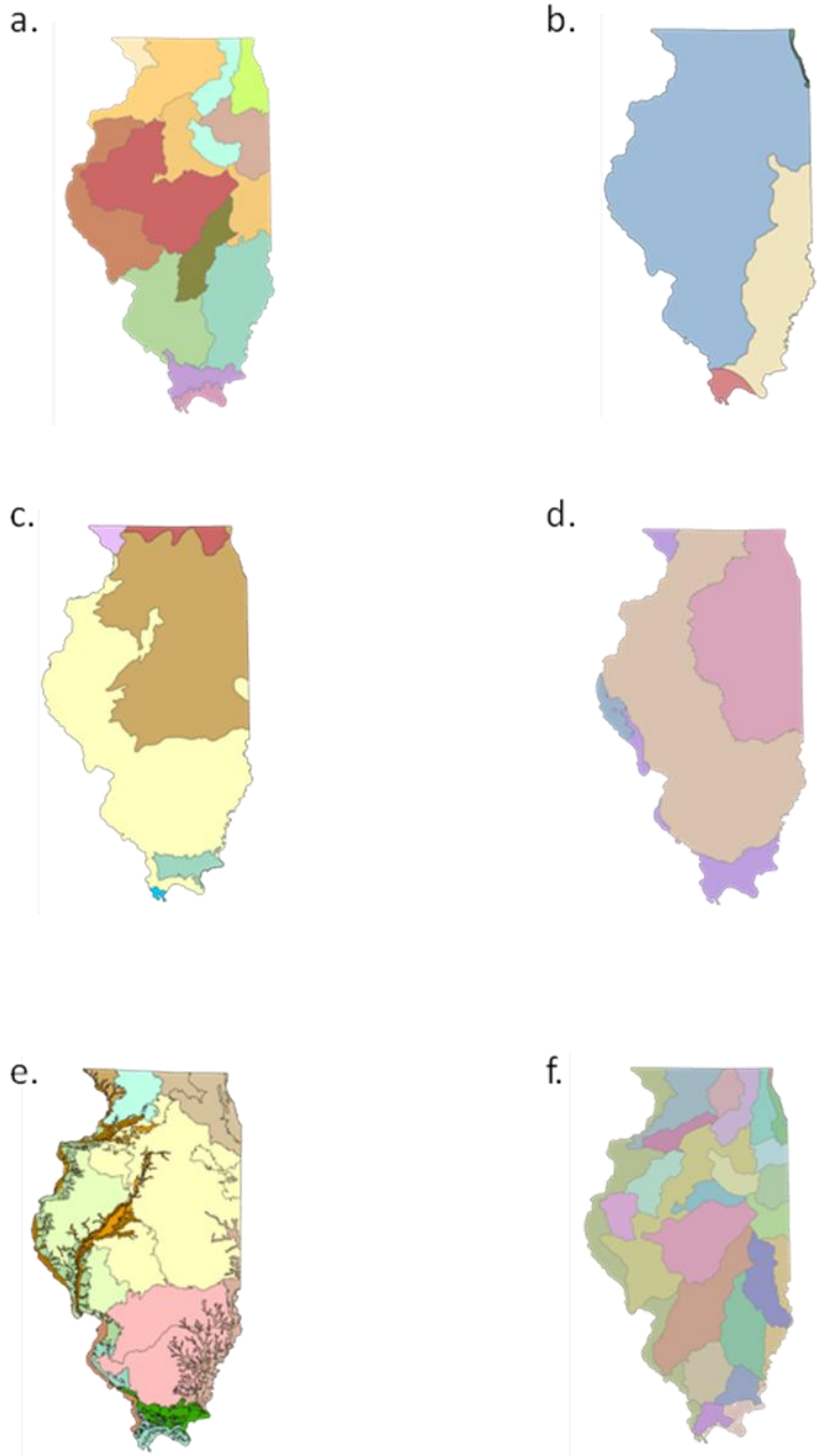


Figure 10. Maps delineating the regionalization schemes considered to address regional variation in habitat measures: a. Fish IBI regions, b. Freshwater ecoregions, c. Ecoregions of Illinois, d. Glacial boundaries, e. Natural Divisions, and f. major watersheds.

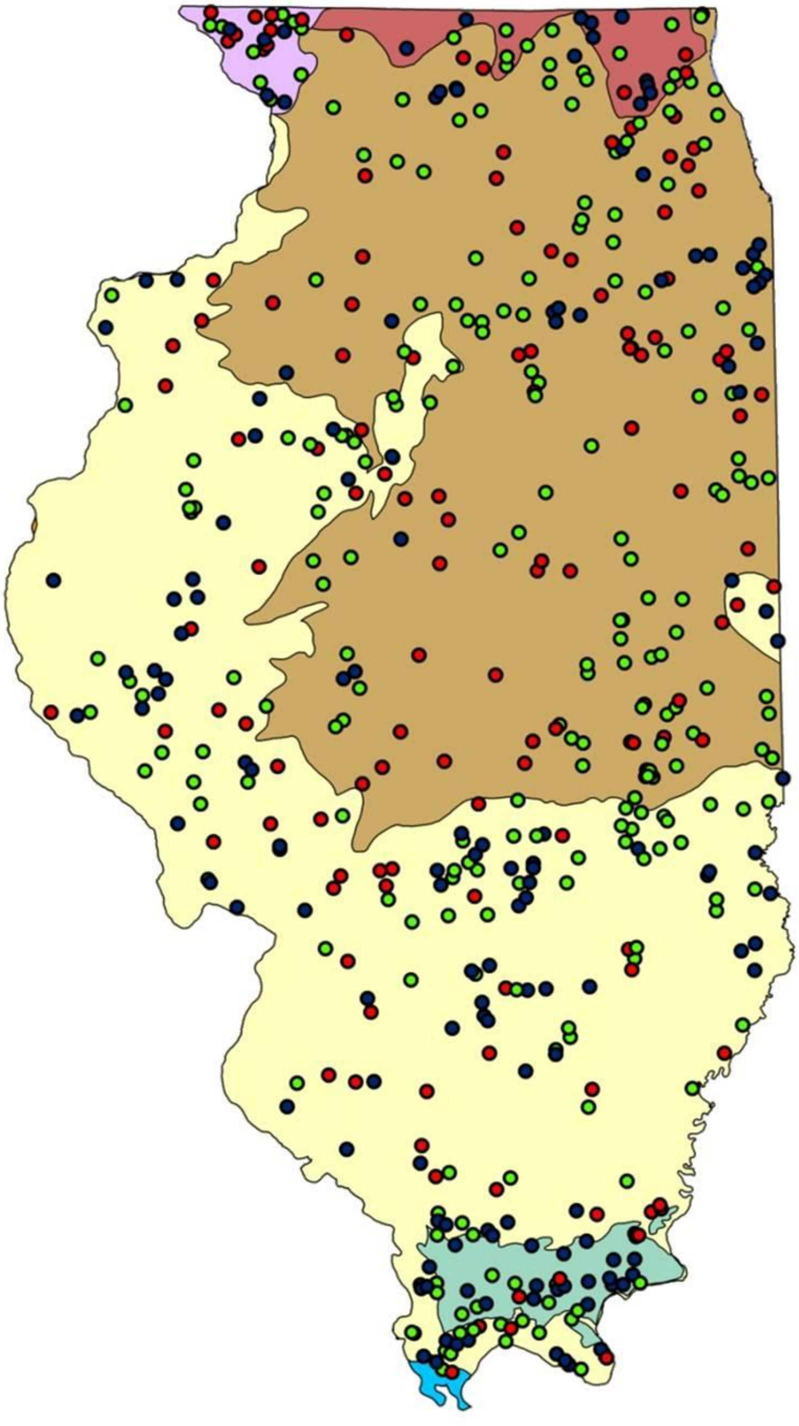


Figure 11. Map of Illinois delineated by ecoregions (Woods et al. 2006) and showing the location of all sampled sites. Blue circles represent sample locations on streams that are least disturbed, green are moderately disturbed and red circles are sample locations on most disturbed stream arcs.

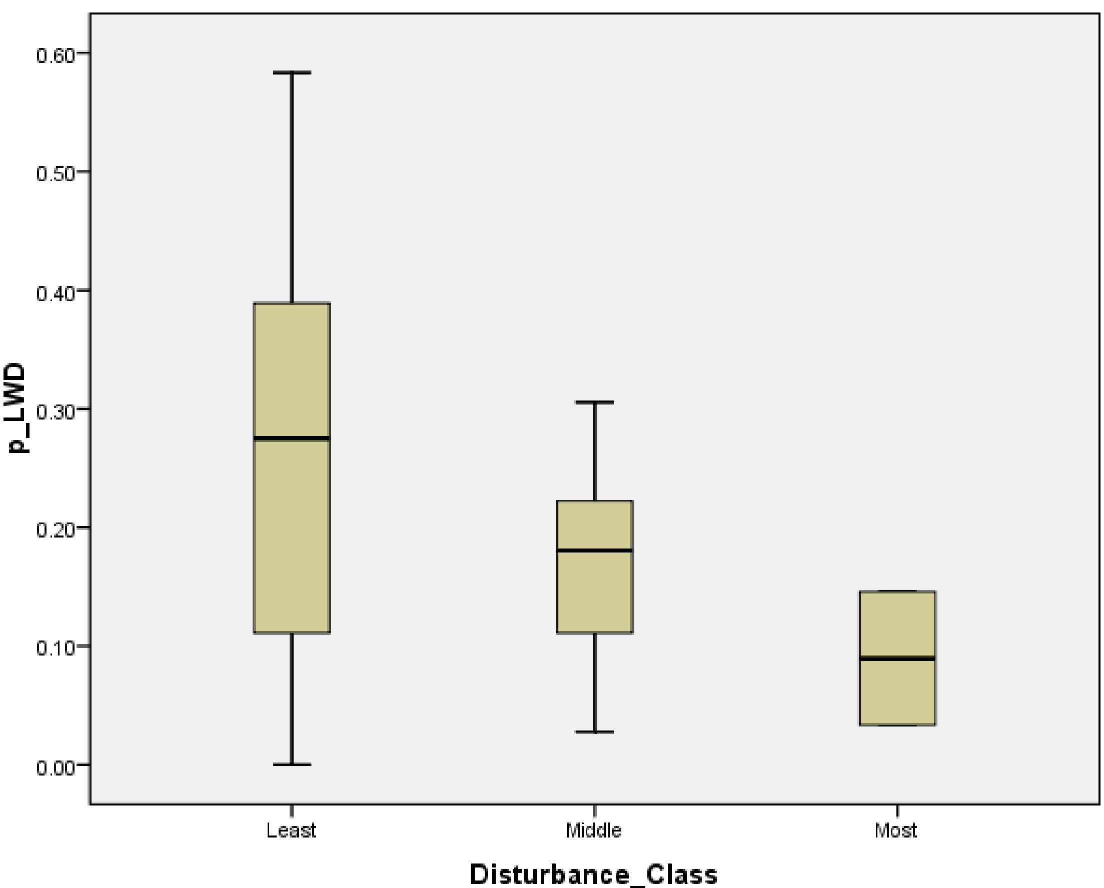


Figure 12. Proportion of large woody debris (p_LWD) by disturbance class.

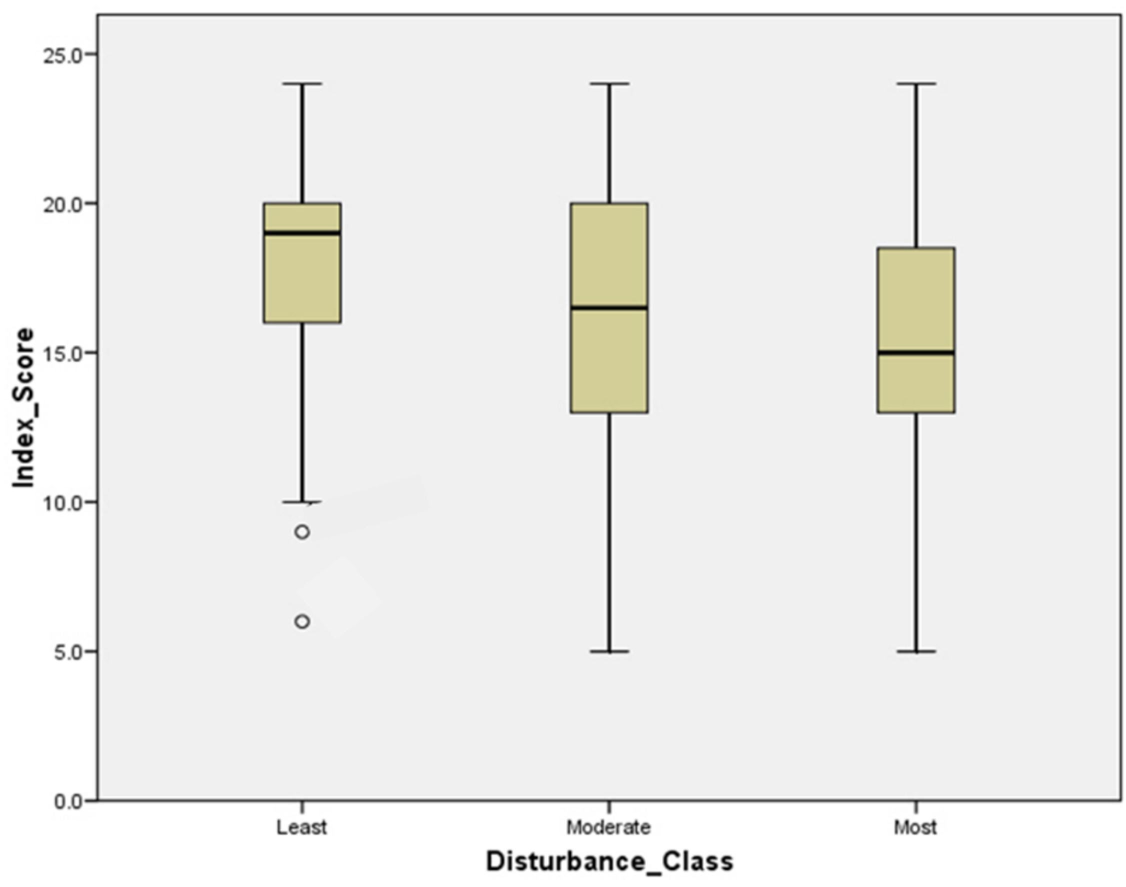


Figure 13. Range of index scores for each disturbance class. A lower index score indicates a less disturbed stream. Index scores range from 5-24.

Appendix A. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
	Substrate - Type	
1	Boulder/cobble	Number of units in which boulders or cobble were listed as dominant
2	Gravel	Number of units in which gravel or fine gravel were listed as dominant
3	Sand	Number of units in which sand was listed as dominant
4	Hardpan	Number of units in which hardpan was listed as dominant
5	Silt	Number of units in which silt was listed as dominant
6	Bedrock	Number of units in which bedrock was listed as dominant
7	Proportion of boulder/cobble	Number of units in which boulders or cobble were listed as dominant divided by total number of units
8	Proportion of gravels	Number of units in which gravel or fine gravel were listed as dominant per reach divided by total number of units
9	Proportion of sand	Number of units in which sand was listed as dominant per reach divided by total number of units
10	Proportion of hardpan	Number of units in which hardpan was listed as dominant per reach divided by total number of units
11	Proportion of silt	Number of units in which silt was listed as dominant per reach divided by total number of units
12	Proportion of bedrock	Number of units in which bedrock was listed as dominant per reach divided by total number of units
13	Predominant substrate in the unit	Substrate that had the highest proportional value for units (if unit has a tie for the dominant substrate, cell is left blank)
14	Predominant substrate in the reach	Taken directly from reach data
15	Dominant substrate	Substrate recoded small to large:

Substrate	Numerical Code
Silt	1
Sand	2
Hardpan	3
Fine gravel	4
Gravel	5
Cobble	6
Boulder	7
Slab Boulder	7
Bedrock	8

ID	Candidate Metric	Description of the metric
16	Next dominant substrate	Substrate recoded small to large, same as Dominant substrate
17	Substrate QHEI	Sum(Dominant substrate + Next dominant substrate + Average embeddedness + Average of deepest fines)
18	Dominant substrate QHEI	Substrate recoded:

Substrate	Numerical Code
Clay	2
Silt	2
Hardpan	4
Bedrock	5
Sand	6
Fine gravel	7
Gravel	7
Cobble	8
Boulder	10
Slab Boulder	10

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
19	Next dominant substrate QHEI	Substrate recoded same as Dominant substrate QHEI
20	Substrate QHEI2	Sum(Dominant QHEI + Next dominant QHEI + Average embeddedness + Average of deepest fines)
21	Dominant substrate for the dominant unit type	Most commonly chosen substrate type in all units marked in reach as dominant unit (e.g. If predominant unit type is pool, then only consider pools.)
	Substrate - Quality	
22	Recoded substrate class	Substrate recoded:

Substrate	Numerical Code
Clay	1
Silt	1
Sand	2
Hardpan	3
Fine gravel	4
Gravel	4
Cobble	5
Boulder	5
Slab Boulder	5
Bedrock	6

ID	Candidate Metric	Description of the metric
23	Proportion of soft substrate	Proportion of units with dominant substrate as sand, silt, of hardpan
24	Proportion of coarse substrate	Proportion of units with dominant substrate as boulder, cobble, gravel, or bedrock
25	Deepest fine	Deepest measure of fines across all units in the reach
26	Deepest fine (no silt-dominant units)	Deepest measure of fines recalculated to include only units that do not have silt marked as dominant substrate
27	Deepest fine run	Deepest measure of fines across all runs in the reach
28	Deepest fine run (no silt-dominant units)	Deepest measure of fines across all runs in the reach not including runs with silt as dominant substrate
29	Deepest fine riffle	Deepest measure of fines across all riffles in the reach
30	Deepest fine riffle (no silt-dominant units)	Deepest measure of fines across all riffles in the reach not including riffles with silt as dominant substrate
31	Deepest fine pool	Deepest measure of fines across all pools in the reach
32	Deepest fine pool (no silt-dominant units)	Deepest measure of fines across all pools in the reach not including pools with silt as dominant substrate
33	Pool (silt-dominant units only)	Number of pools with silt marked as the dominant substrate
34	Proportion of pool (silt-dominant units only)	Number of pools with silt as dominant substrate divided by total number pools (if there are no pools in the reach, the cell is left blank)
35	Pool silt both	Number of pools with silt marked as the dominant or subdominant substrate
36	Proportion of pool silt both	Number of pools with silt as dominant or subdominant substrate divided by total number of pools (if there are no pools in the reach, the cell is left blank)
37	Number of units (silt-dominant units only)	Number of units with silt marked as the dominant substrate
38	Proportion of units (silt-dominant units only)	Number of units with silt as dominant or subdominant divided by total number units
39	Number of units silt both	Number of units with silt marked as the dominant or subdominant substrate
40	Proportion of units silt both	Number of units with silt as dominant or subdominant divided by total number of units
41	Number of units not embedded	Number of units in reach marked as not embedded (cell is left blank if all units are n/a)
42	Proportion of units not embedded	Number of units not embedded divided by total number units. (cell is left blank if all units are n/a)
43	Proportion of macrophytes	Number of units that have any macrophyte cover divided by total number of units

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
44	Average of deepest fines	Average of deepest fines across the units
45	Average of embeddedness	Average of the embeddedness across the units (embeddedness is scored 0 = 0%, 1 = 1-25%, 2 = 26-50%,3 = 51-75%,4 = 76-100%)
46	Average of percent embed	Average of the embeddedness across the units (embeddedness is scored 0,25,50,75,100)
47	Substrate stability	Sum of the Proportions of boulder and cobble + Proportion of aquatic macrophytes
48	Dominant substrate size	Dominant substrate from reach datasheet recoded using sizes instead of numbers:

Substrate	Numerical Code
Clay	0.001
Hardpan	0.001
Silt	0.05
Sand	1.00
Fine gravel	5.00
Gravel	36.00
Cobble	160.00
Boulder	256.00
Slab Boulder	256.00
Bedrock	500.00

ID	Candidate Metric	Description of the metric
49	Next dominant substrate size	Next dominant substrate from reach datasheet recoded using sizes instead of numbers (same as Dominant substrate size)
50	Average of dominant substrate size	Dominant substrate size from unit averaged across all units in the reach
51	Average of next dominant substrate size	Next dominant substrate size from unit averaged across all units in the reach
52	Average substrate size	Dominant substrate size and next dominant substrate size from unit then both (all) are averaged across all units in the reach
53	Ratio dominant next size	Of the dominant and next dominant substrate for the reach, ratio of the largest to the smallest
54	Proportion of boulder/cobble/gravel	Sum(Proportion of boulder and cobble + Proportion of slab boulder + Proportion of cobble + Proportion of gravel)
55	Number of dominant substrate	Count of the different types of substrate checked as dominant
56	Number of all substrate	Count of the different types of substrate checked as dominant and next dominant
57	Proportion of size substrate	Substrates multiplied by their size, then summed across the reach
58	Dominant substrate recoded	Dominant substrate for the reach recoded so numbers are in order of size:

Substrate	Numerical Code
Silt	1
Clay	3
Hardpan	3
Sand	4
Fine gravel	5
Gravel	6
Cobble	7
Boulder	8
Slab Boulder	9
Bedrock	10

ID	Candidate Metric	Description of the metric
59	Next Dominant substrate recoded	Next dominant substrate for the reach recoded so numbers are in order of size (same as Dominant substrate recoded)
60	Recoded substrate ratio	Of both the dominant and next dominant substrate for the reach, ratio of the largest to the smallest using the recoded numbers as listed for Dominant substrate recoded

ID	Candidate Metric	Description of the metric
	In-stream cover-type	
61	Number of cover types reach	Count of the different cover types marked (number 0-9, not frequency)
62	Number of cover types runs	Count of the different cover types marked in only the runs (number 0-9, not frequency)
63	Number of cover types pools	Count of the different cover types cited in only the pools (number 0-9, not frequency)
64	Proportion of units with other	Proportion of units with "other" as a cover type in a reach (total number of units marked divided by total possible units)
65	Proportion of junk	Proportion of unite with “other” that was labeled as some sort of human litter (total number of units marked divided by total possible units)
66	Proportion of undercut banks	Proportion of undercut banks as cover in all units except riffles (total number of units marked divided by total possible units)
67	Proportion of overhanging vegetation	Proportion of overhanging vegetation as cover in all units except riffles (total number of units marked divided by total possible units)
68	Proportion of rootwad cover	Proportion of rootwads as cover in all units except riffles (total number of units marked divided by total possible units)
69	Proportion of boulder cover	Proportion of boulders as cover in all units except riffles (total number of units marked divided by total possible units)
70	Proportion of large woody debris cover	Proportion of logs or woody debris + aggregate large woody debris as cover in all units except riffles (total number of units marked divided by total possible units)
71	Proportion of rootmat cover	Proportion of rootmats as cover in all units except riffles (total number of units marked divided by total possible units)
72	Proportion of overhanging vegetation and rootmat cover	Proportion of overhanging vegetation + rootmats as cover in all units except riffles (total number of units marked divided by total possible units)
73	Proportion of wood	Proportion of logs or woody debris + aggregate large woody debris + rootwads as cover in all units except riffles (total number of units marked divided by total possible units)
74	Proportion of undercut banks and overhanging vegetation	Proportion of undercut banks + over hanging vegetation as cover in all units except riffles (total number of units marked divided by total possible units)
75	Proportion of aquatic macrophytes	Proportion of aquatic macrophytes as cover in all units except riffles (total number of units marked divided by total possible units)
76	Number of pools >70 cm	Number of pools >70 cm (70 cm is used in QHEI as a "quality" pool)
77	Number of pools >50 cm	Number of pools >50 cm
78	Proportion of pools >70 cm	Proportion of pools >70 cm deep (calculated with only "pool" units: number of pools >70 cm divided by the total number of pools)
79	Proportion of pools >70 cm (all units)	Proportion of pools >70 cm deep (calculated with all units in the reach: the number of pools >70 cm was divided by the total number of units)
80	Proportion of pools >50 cm	Number of pools >50 cm divided by total number of pools
81	Proportion of pools >50 cm (all units)	Number of pools >50 cm divided by total number of units (calculated with all units in the reach: the number of pools >50 cm was divided by the total number of units)
82	Number of runs >70 cm	Number of runs >70 cm
83	Number of runs >50 cm	Number of runs >50 cm
84	Proportion of runs >70 cm	Number of runs >70 cm divided by total number of runs
85	Proportion of runs >70 cm (all units)	Number of runs >70 cm divided by total number of units (calculated with all units in the reach: the number of runs >70 cm was divided by the total number of units)
86	Proportion of runs >50 cm	Number of runs >50 cm divided by total number of runs
87	Proportion of runs >50 cm (all units)	Number of runs >50 cm divided by total number of units (calculated with all units in the reach: the number of runs >50 cm was divided by the total number of units)
88	Number of units >70 cm	Number of units >70 cm
89	Number of units >50 cm	Number of units >50 cm

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
90	Proportion of units >70 cm	Number of units >70 cm divided by total number of units
91	Proportion of units >50 cm	Number of units >50 cm divided by total number of units
	In-stream cover-amount	
92	Proportion of units with no cover	Number of units in each reach with no cover divided by total number units
93	Proportion of units with some cover	Proportion of units in each reach that have at least some cover marked.
94	Proportion of 0s for cover	Number of 0s marked divided by the possible number of times "0" could have been marked (= 9 * number of units)
95	Proportion of 1s for cover	Number of 1s marked divided by the possible number of times "1" could have been marked (= 9 * number of units)
96	Proportion of 2s for cover	Number of 2s marked divided by the possible number of times "2" could have been marked (= 9 * number of units)
97	Proportion of 3s for cover	Number of 3s marked divided by the possible number of times "3" could have been marked (= 9 * number of units)
98	Pool overhanging-root mats	Sum of (Overhanging vegetation + root mats) for each pool, then the sums are averaged across the reach
99	Pool wood	Sum of the sums of large woody debris + aggregate wood + rootwads for each pool divided by 3*number of pools in reach
100	Run overhanging-root mats	Sum of (Overhanging vegetation + root mats) summed for each run, then the sums are averaged across the reach
101	Run wood	Sum of (Large woody debris + Aggregate wood + Rootwads) summed for each run, then the sums are averaged across the reach
102	Riffle overhanging-root mats	Sum of (Overhanging vegetation + root mats) summed for each run, then the sums are averaged across the reach
103	Riffle wood	Sum of (Large woody debris + Aggregate wood + Rootwads) summed for each run, then the sums are averaged across the reach
104	Proportion of total cover	All numbers circled are summed then divided by [(3 * 9) * number of units]
105	Count of cover	Count of the number cover types per reach
106	Cover QHEI	Sum of (Proportion of undercut + Proportion of overhanging + Proportion of rootmat + Proportion of rootwad + Proportion of boulder + Proportion of aquatic macrophytes + Proportion of large woody debris + Proportion of pools>70cm)
	Channel quality/stability	
107	Channel evolution	Coded 1-5:
108	Chan evolution class	Channel evolution recoded 1,2,3:

107 – Coded 1-5:

Channel Evolution	Numerical Code
Stable (1)	1
Incising (2)	3
Widening (3)	3
Stabilizing (4)	4
Stable (5)	5

108 – Channel evolution recoded 1,2,3:

Channel Evolution	Numerical Code
Stable (1)	3
Incising (2)	1
Widening (3)	1
Stabilizing (4)	2
Stable (5)	3

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
109	Chan evolution class2	Channel evolution recoded 1,2,3,4:
110	Chan evolution class3	Channel evolution recoded 1,2,3,4:
111	Chan evolution class4	Channel evolution recoded 1,2,3:
112	Chan evolution class5	Channel evolution recoded 1,2,3,4:
113	Width : depth	Average of the upper, middle, and downstream width : depth ratios
114	Shading	Coded:
115	Percent shade	Shading recoded:

109 – Chan evolution class2:

Channel Evolution	Numerical Code
Stable (1)	1
Incising (2)	2
Widening (3)	3
Stabilizing (4)	4
Stable (5)	1

110 – Chan evolution class3:

Channel Evolution	Numerical Code
Stable (1)	1
Incising (2)	2
Widening (3)	3
Stabilizing (4)	3
Stable (5)	4

111 – Chan evolution class4:

Channel Evolution	Numerical Code
Stable (1)	1
Incising (2)	2
Widening (3)	3
Stabilizing (4)	3
Stable (5)	2

112 – Chan evolution class5:

Channel Evolution	Numerical Code
Stable (1)	1
Incising (2)	2
Widening (3)	3
Stabilizing (4)	4
Stable (5)	2

114 – Shading:

Shading	Numerical Code
Lack of canopy; full sunlight reaching the water	0
Most water surface receiving sunlight	1
Half water surface shaded, half full sunlight	2
Water mostly shaded with some sunlight	3
Water surface completely shaded	4

115 – Percent shade:

Shading	Numerical Code
Lack of canopy; full sunlight reaching the water	0
Most water surface receiving sunlight	25
Half water surface shaded, half full sunlight	50
Water mostly shaded with some sunlight	75
Water surface completely shaded	100

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
116	Average bare	Amount circled for "Bare" -average of left and right stream banks (range 0-3)
117	Channelized	0 = no, 1 = yes
118	Channel development	Sum (Average buffer + Average riparian + Channel evolution)
	Riparian quality /erosion	
119	Left buffer	Coded:

Buffer description	Numerical Code
None (<1m)	0
Very Narrow (1-5m)	1
Narrow (5-10m)	2
Moderate (10-50m)	3
Wide (50-100m)	4
Very Wide (<100m)	5

ID	Candidate Metric	Description of the metric
120	Right buffer	Coded the same as Left buffer
121	Min buffer	Smaller width of the right or left buffer width
122	Max buffer	Larger width of the right or left buffer width
123	Average buffer	Sum (Left buffer width + Right buffer width) divided by 2
124	Buffer riparian	Sum of coded (Average buffer width + Average riparian type)
125	Buffer bare	Aveerage buffer minus average bare + 3 (range 0-8)
126	Left buffer ranked	Left buffer recoded:

Buffer description	Numerical Code
None (<1m)	0
Very Narrow (1-5m)	5
Narrow (5-10m)	10
Moderate (10-50m)	50
Wide (50-100m)	100
Very Wide (<100m)	150

ID	Candidate Metric	Description of the metric
127	Right buffer ranked	Coded same as Left buffer ranked
128	Average buffer ranked	Sum (Left buffer ranked + Right buffer ranked) divided by two
129	Adjacent land use	0 = forest, 1 = urban, 2 = agriculture (averaged across the left and right banks)
130	Bank erosion	Sum of left and right bare bank value from the stream reach bank cover
131	Bank stability	Sum of left and right values (trees + herbaceous + wood - bare) from the stream reach bank cover
132	Cover structure	Count of left and right values (trees + herbaceous + wood + bedrock) from the stream reach bank cover
133	Average riparian type	Coded riparian types averaged across the left and right banks. Coded as:

Riparian description	Numerical Code
If Buffer width = 0	0
Herbaceous	1
Mixed	2
Woody Shrubs	3
Trees	4

ID	Candidate Metric	Description of the metric
134	Bank erosion ranked	Sum of left and right "bare" values bank from the stream reach bank cover
135	Bank stability ranked	Sum of left and right stream bank values (trees + herbaceous + wood - bare)
136	Riparian QHEI	Sum (Average buffer + Average riparian type + Channel evolution class)

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
	Pool/riffle quality	
137	Proportion of riffles	Proportion of units that are labeled as a riffle in the reach
138	Proportion of riffle >10cm all units	Proportion of units that are riffles and are >10 cm deep divided by total number units
139	Number of lateral pools	Number of lateral pools in each reach
140	Number of mid-channel pools	Number of mid-channel pools in each reach
141	Number of pools	Total number of pools in each reach
142	Number of riffles	Number of riffles in each reach
143	Pool max average	Average of the max depth across all pools in the reach
144	Pool min average	Average of the min depth across all pools in the reach
145	Pool mean average	Average of the mean depth across all pools in the reach
146	Pool max variance	Variance of the max depth across all pools in the reach
147	Pool mean variance	Variance of the mean depth across all pools in the reach
148	Count units not pools	Number of units that are not pools
149	Proportion of pools	Number of pools in the reach divided by number units in reach
150	Proportion of mid-channel pools	Proportion of units that are mid-channel pools
151	Proportion of lateral pools	Proportion of units that are lateral pools
152	Pool variance score	(see table below)

Pool Description	Numerical Code
No pools in the reach	0
The whole reach is one pool, or all channel units are marked as mid-channel pools	1
There are more mid-channel pools than lateral pools	2
There are more lateral pools than mid-channel pools	3
The number of mid-channel and lateral pools is the same	4

ID	Candidate Metric	Description of the metric
153	Mean range of pool cross-sections	Average of max depth of all pools' cross-sections in the reach minus the average of the minimum depth of all pools' cross-sections in the reach
154	Max riffle depth average	Max of the average riffle depth in the reach
155	Average max depth riffles	Average of the max depth in riffles
156	Pool : riffle ratio	Number of pools divided by number of riffles
157	Average of pool variance	Average of the variances in the cross-section depths in each pool across the reach
158	Pool quality	An integrated measure based on pool type, depth, cover, and development. Based on a sum of scores: One point is given for each criteria met, range 0-6. If there are no pools in the reach, the total score is 0 regardless of scores 2-6.

Pool Description	Score: Yes	Score: No
1. Are there any pools in the reach?	1	0
2. Are there both lateral and mid-channel pools in the reach?	1	0
3. Is the reach channelized?	0	1
4. Is there any cover marked in the pools?	1	0
5. Are there any pools >70 cm deep?	1	0
6. IF YES to #5, are there any pools <70cm deep? (score = 0 if #5 = 0)	1	0

ID	Candidate Metric	Description of the metric
159	Pool score	Based on a sum of scores: One point is given for each criteria met, range 0-4. If there are no pools in the reach, the total score is 0 regardless of scores 2-4.

Pool Description	Score Yes	Score No
1. Are there any pools in the reach?	1	0
2. Are there both lateral and mid-channel pools in the reach?	1	0
3. Are there any pools >70 cm deep?	1	0
4. IF YES to #5, are there any pools <70cm deep? (score = 0 if #5 = 0)	1	0

ID	Candidate Metric	Description of the metric
160	Max of pool max	Deepest pool depth across the reach
161	Deepest fines in pools	Deepest measurement of fines in all pools across the reach
162	Average of fines in pools	Average of depth of fines in all pools across the reach
163	Average substrate size in pools	Dominant and sub dominant substrate sizes averaged (see number 49 for sizes)
164	Proportion of cover in pools	Sum of all cover scores across all pools divided by (number of pools*9)
	Other units	
165	Number of runs	Number of runs in the reach
166	Number of transitional units	Number of transitional areas in the reach
167	Proportion of runs	Proportion of units that are runs in the reach
168	Proportion of transitional units	Proportion of units that are transitional units
169	Number of unit types	Number of unit types in a reach (range 1-4)
170	Most common unit	The unit type that occurs most often in the reach, if it's a tie, the cell is blank
171	Reach unit types match	Does the most often unit type match what was selected as predominant for the reach (0,1)
172	Total number of units	Total number of units in each reach
173	Predominant channel type	Collected at the reach scale (pool, riffle, or run)
174	Max of max depth unit	Deepest max depth across all the units
175	Unit variance	Sum (number of units + number unit types)
	Thalweg	
176	Thalweg min	Smallest of the thalweg depths across the reach
177	Thalweg max	Largest of the thalweg depths across the reach
178	Thalweg mean	Mean of the thalweg depths across the reach
179	Thalweg max : min	Ratio of the largest to the smallest depths (max depth divided by min depth)
180	Thalweg mean : max	The average thalweg depth divided by the max thalweg depth
181	Thalweg range	The max thalweg depth minus the min thalweg depth
182	Thalweg variance	Variance calculated using the 10 thalweg depths
183	Variance of max depth unit	Variance calculated using the max depth of all units across the reach
184	Run max variance	Variance of the max depths across the runs in each reach
185	Run max mean	Mean of the max depths across the runs in each reach
	Flow	
186	Predominant flow reach	Collected at the reach scale (no detectable, slow, moderate, fast)
187	Predominant flow units	The type of flow most commonly chosen in the units, if it's a tie, cell is blank
188	Flow reach units match	Comparison of "predominant flow reach" with "predominant flow units" (yes/no)

Appendix A cont. A list of all candidate metrics examined.

ID	Candidate Metric	Description of the metric
189	Proportion of no flow units	Proportion of units marked as "no detectable" flow
190	Proportion of slow flow units	Proportion of units marked as "slow" flow
191	Proportion of moderate flow units	Proportion of units marked as "moderate" flow
192	Proportion of fast flow units	Proportion of units marked as "fast" flow
193	Number of flow types	Number of flow types in a reach (number 1-4)
194	Proportion of slow-no flow	Number of units marked as slow or no flow divided by total number units
195	Proportion of moderate-fast flow	Number of units as moderate or fast flow divided by total number units
196	Proportion of slow flow	Number of units marked as slow flow divided by total number units
197	Proportion of fast flow	Number of units as fast flow divided by total number units
198	Slow : fast	Proportion of slow flow divided by Proportion of fast flow
199	Mean velocity	An average of the flows across units (no detectable = 0, slow = 1, moderate = 2, fast = 3)
200	Current QHEI	Sum (Thalweg max + Count flow types)
201	Hydro diversity	Sum (Count of channel unit types + Count of flow types)

Appendix B. Example field sheets including information collected at each site.

HABITAT EVALUATION FORM

Station Code: | Stream: | Location (include road crossing):

Date: | Scorer(s): | Gaz pg:

REACH CHARACTERISTICS Page __1__ of _____

Check one box per bank. River right looking upstream.

Buffer Width **(Top of Bank)**

L R (Per Bank)

- ☐ ☐ Very Wide > 100m
- ☐ ☐ Wide 50-100m
- ☐ ☐ Moderate 10-50m
- ☐ ☐ Narrow 5-10m
- ☐ ☐ Very narrow 1-5m
- ☐ ☐ None <1m (if checked, list land use adjacent to stream)

L __________

R __________

Riparian Type

L R (Predominant Per Bank)

- ☐ ☐ Trees
- ☐ ☐ Woody/Shrub
- ☐ ☐ Herbaceous
- ☐ ☐ Mixed

Stream Bank Vegetation

1=Sparse, 2=Intermediate, 3=Abundant

Left		Right
0 1 2 3	Herbaceous	0 1 2 3
0 1 2 3	Woody/Shrub	0 1 2 3
0 1 2 3	Trees	0 1 2 3
0 1 2 3	Bare	0 1 2 3
0 1 2 3	Bedrock	0 1 2 3

Predominant Channel Type

Pool

Riffle

Run

Total # of Channel Units: ______

Predominant Substrate in Reach

(1=Predominant, 2=Next Dominant)

- ☐ Boulder (>256 mm)
- ☐ Slab Boulder (>256 mm)
- ☐ Cobble (64-256 mm)
- ☐ Gravel (8-64mm)
- ☐ Fine Gravel (2-8 mm)
- ☐ Sand
- ☐ Hardpan
- ☐ Silt
- ☐ Bedrock

Predominant Flow in Reach

Check one

- ☐ Fast
- ☐ Moderate
- ☐ Slow
- ☐ No detectable flow

Shading of Water Surface

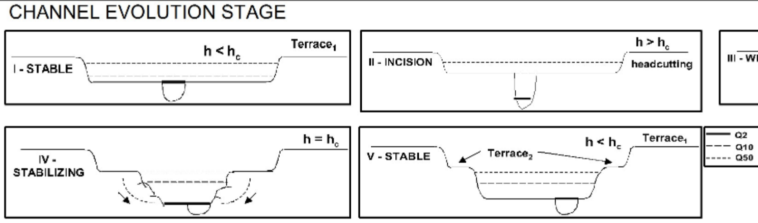
- ☐ Water surface completely shaded
- ☐ Water mostly shaded with some sunlight
- ☐ Half water surface shaded, half full sunlight
- ☐ Most water surface receiving sunlight
- ☐ Lack of canopy; full sunlight reaching water

Thalweg Depths in Reach

1 ________ m
2 ________ m
3 ________ m
4 ________ m
5 ________ m
6 ________ m
7 ________ m
8 ________ m
9 ________ m
10 ________ m

Comments:

CHANNEL EVOLUTION STAGE



Predominant Channel Stage:

h=streambank height; hc = critical streambank height (slope failure is imminent depending on the strength of the soils in the bank)

ADDITIONAL STREAM INFORMATION

Water Level

- ☐ Rising
- ☐ Normal/Base Flow
- ☐ Decreasing
- ☐ Pooled

Stream Modifications

Check all that apply

- ☐ Outfalls/pipes
- ☐ Canopy Removal
- ☐ Dredging
- ☐ Artificial cover/substrate
- ☐ Impoundments
- ☐ Leveed
- ☐ BMPs (List practices)
- ☐ Channelized

	Wetted Width	Thalweg Depth
DS	m	m
MID	m	m
UP	m	m
Mean	m	m

Reach Length:______________m

GPS Location (NAD83)

Latitude: ________

Longitude: ________

Photos Taken: ☐ Yes # Taken_______ ☐ No

Comments: Reach starts ____m upstream/downstream from bridge.

Appendix B cont. Example field sheets including information collected at each site.

Station Code: Date: Scorer(s): Page _____ of _____

Unit #:_________ CHANNEL UNIT (Circle One): Lateral Pool Mid-Channel Pool Riffle Run Transitional

Substrate Type (1=Predominant, 2=Next Dominant)
- ☐ Boulder (>256 mm)
- ☐ Slab Boulder (>256 mm)
- ☐ Cobble (64-256 mm)
- ☐ Gravel (8-64mm)
- ☐ Fine Gravel (2-8 mm)
- ☐ Sand
- ☐ Hardpan
- ☐ Silt
- ☐ Bedrock

Cover (0=None, 1=Sparce, 2=Intermediate, 3=Abundant)
- 0 1 2 3 Undercut Bank
- 0 1 2 3 Overhanging Vegetation
- 0 1 2 3 Rootwads
- 0 1 2 3 Boulder
- 0 1 2 3 Aquatic Macrophytes
- 0 1 2 3 Logs or Woody Debris
- 0 1 2 3 Aggregate LWD
- 0 1 2 3 Rootmats
- 0 1 2 3 Other___________

Substrate Embeddedness (1°substrate)
Applies when 1° substrate is ≥fine gravel
- ☐ Not Embedded
- ☐ 0-25% Embedded
- ☐ 25-50% Embedded
- ☐ 50-75% Embedded
- ☐ 75-100% Embedded
- ☐ Pool (N/A)
- ☐ 1°substrate is fine (N/A)

Depth of Fines as Bottom Cover
- ☐ None
- ☐ 1-25 mm
- ☐ 25-50 mm
- ☐ 50-75 mm
- ☐ > 75 mm

Cross Section Depths
(Pools Only) Measure from LAB to RAB
1 _____ m
2 _____ m
3 _____ m
4 _____ m
5 _____ m
6 _____ m
7 _____ m
8 _____ m

Max Depth: ______ m

Predominant Flow
(Circle One)
Fast
Moderate
Slow
No Detectable Flow

Comments:

Unit #:_________ CHANNEL UNIT (Circle One): Lateral Pool Mid-Channel Pool Riffle Run Transitional

Substrate Type (1=Predominant, 2=Next Dominant)
- ☐ Boulder (>256 mm)
- ☐ Slab Boulder (>256 mm)
- ☐ Cobble (64-256 mm)
- ☐ Gravel (8-64mm)
- ☐ Fine Gravel (2-8 mm)
- ☐ Sand
- ☐ Hardpan
- ☐ Silt
- ☐ Bedrock

Cover (0=None, 1=Sparce, 2=Intermediate, 3=Abundant)
- 0 1 2 3 Undercut Bank
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- 0 1 2 3 Rootwads
- 0 1 2 3 Boulder
- 0 1 2 3 Aquatic Macrophytes
- 0 1 2 3 Logs or Woody Debris
- 0 1 2 3 Aggregate LWD
- 0 1 2 3 Rootmats
- 0 1 2 3 Other___________

Substrate Embeddedness (1°substrate)
Applies when 1° substrate is ≥fine gravel
- ☐ Not Embedded
- ☐ 0-25% Embedded
- ☐ 25-50% Embedded
- ☐ 50-75% Embedded
- ☐ 75-100% Embedded
- ☐ Pool (N/A)
- ☐ 1°substrate is fine (N/A)

Depth of Fines as Bottom Cover
- ☐ None
- ☐ 1-25 mm
- ☐ 25-50 mm
- ☐ 50-75 mm
- ☐ > 75 mm

Cross Section Depths
(Pools Only) Measure from LAB to RAB
1 _____ m
2 _____ m
3 _____ m
4 _____ m
5 _____ m
6 _____ m
7 _____ m
8 _____ m

Max Depth: ______ m

Predominant Flow
(Circle One)
Fast
Moderate
Slow
No Detectable Flow

Comments:

Unit #:_________ CHANNEL UNIT (Circle One): Lateral Pool Mid-Channel Pool Riffle Run Transitional

Substrate Type (1=Predominant, 2=Next Dominant)
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- ☐ Hardpan
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- 0 1 2 3 Rootwads
- 0 1 2 3 Boulder
- 0 1 2 3 Aquatic Macrophytes
- 0 1 2 3 Logs or Woody Debris
- 0 1 2 3 Aggregate LWD
- 0 1 2 3 Rootmats
- 0 1 2 3 Other___________

Substrate Embeddedness (1°substrate)
Applies when 1° substrate is ≥fine gravel
- ☐ Not Embedded
- ☐ 0-25% Embedded
- ☐ 25-50% Embedded
- ☐ 50-75% Embedded
- ☐ 75-100% Embedded
- ☐ Pool (N/A)
- ☐ 1°substrate is fine (N/A)

Depth of Fines as Bottom Cover
- ☐ None
- ☐ 1-25 mm
- ☐ 25-50 mm
- ☐ 50-75 mm
- ☐ > 75 mm

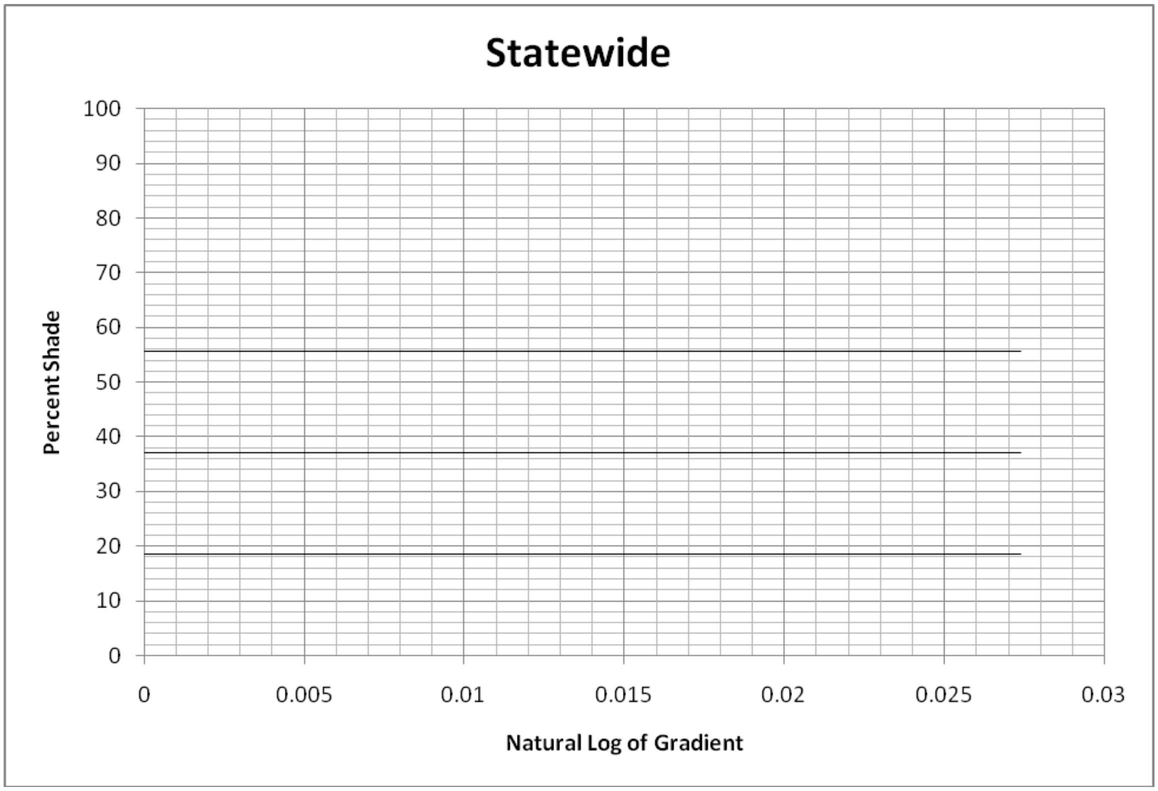
Cross Section Depths
(Pools Only) Measure from LAB to RAB
1 _____ m
2 _____ m
3 _____ m
4 _____ m
5 _____ m
6 _____ m
7 _____ m
8 _____ m

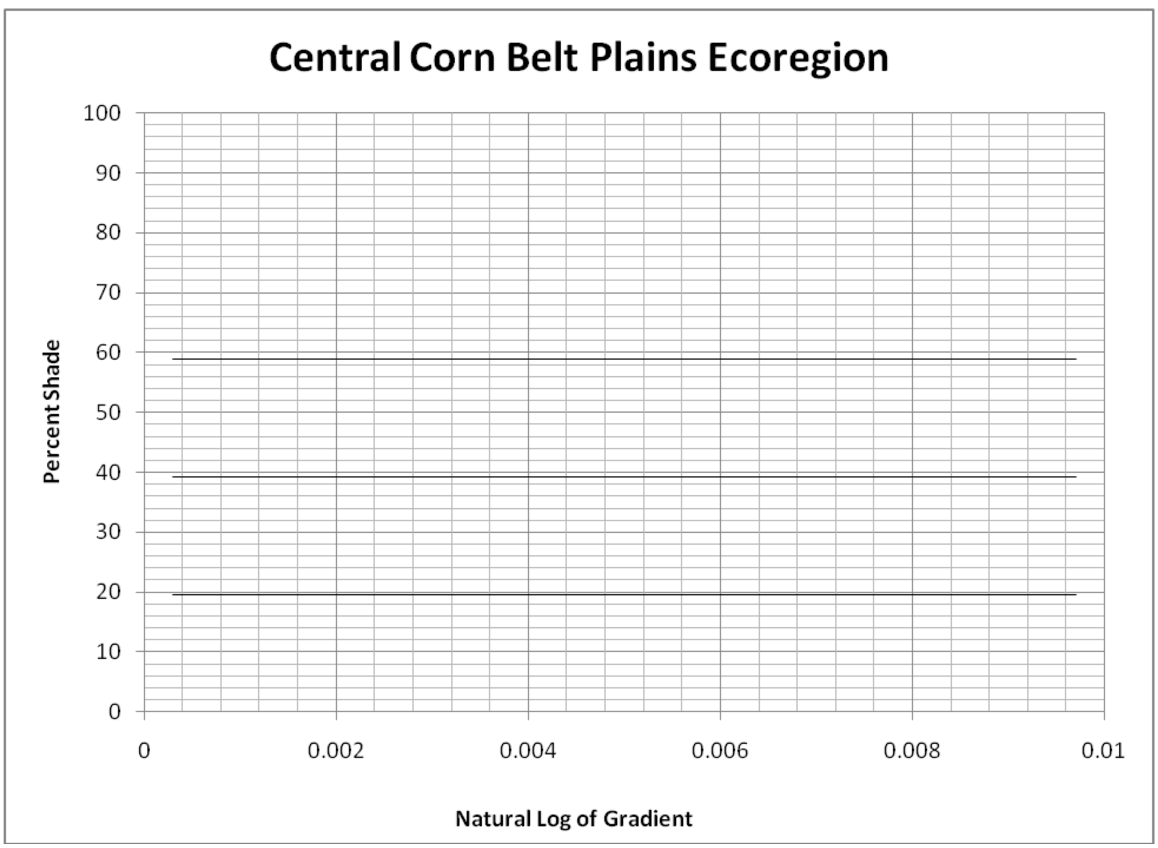
Max Depth: ______ m

Predominant Flow
(Circle One)
Fast
Moderate
Slow
No Detectable Flow

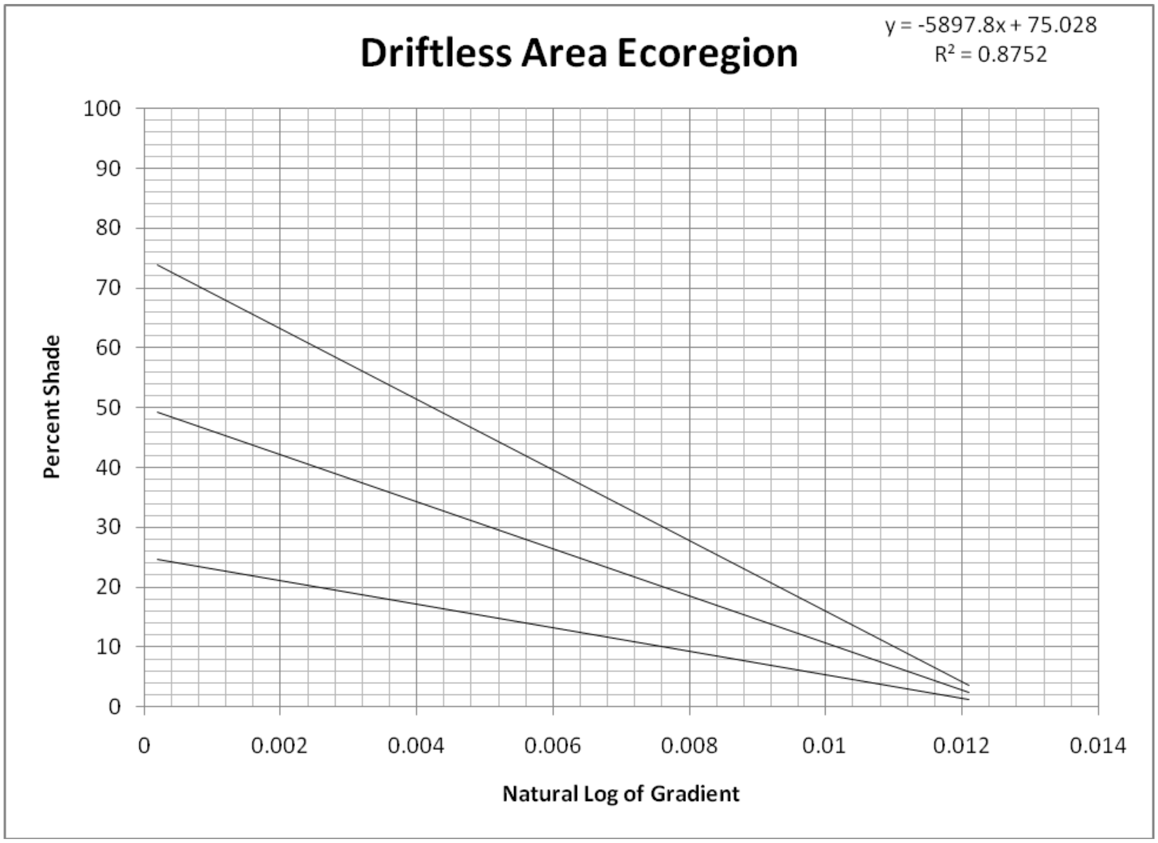
Comments:

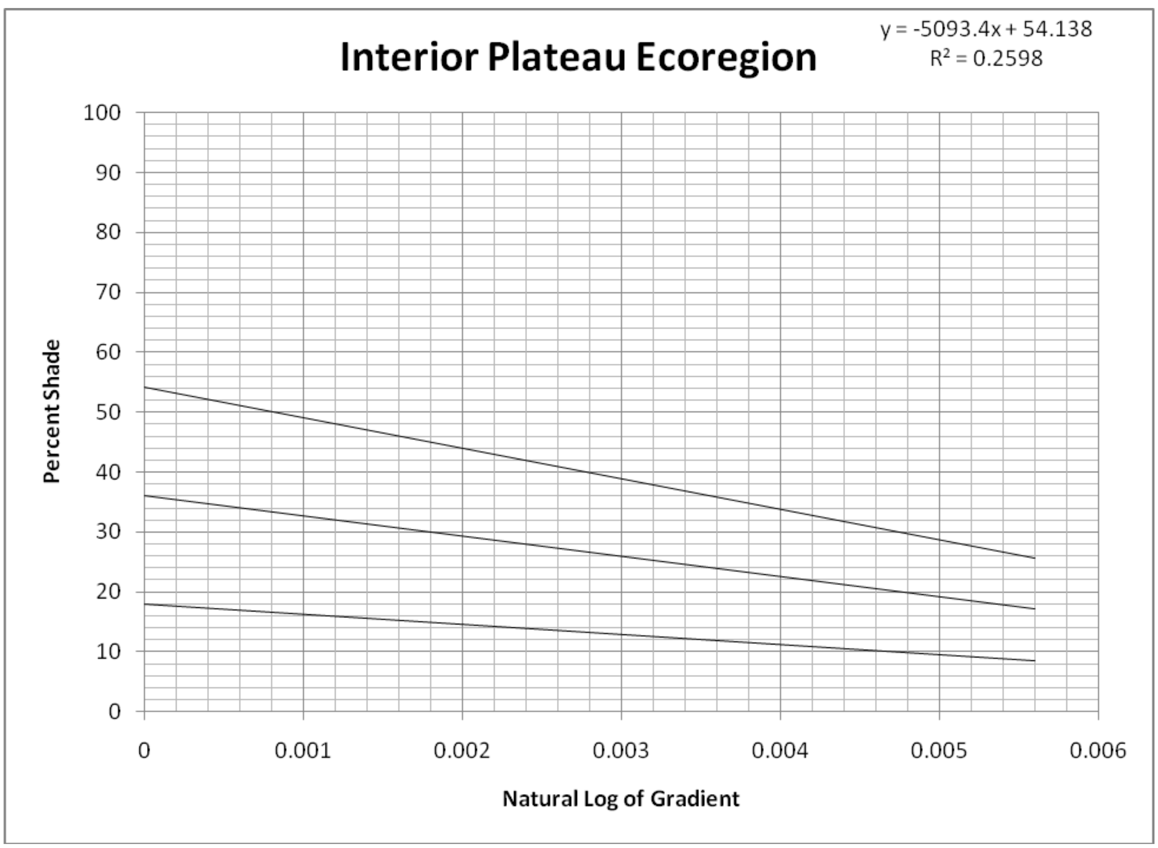
Appendix C. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



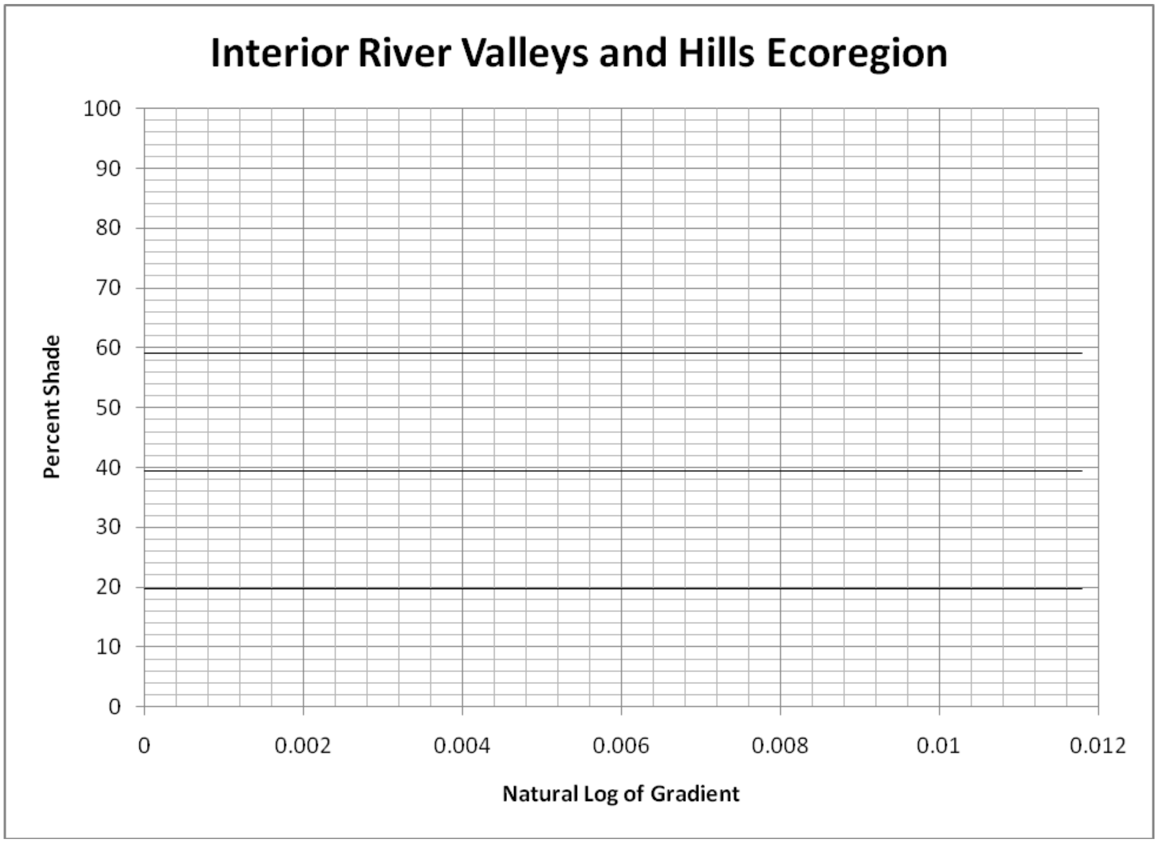


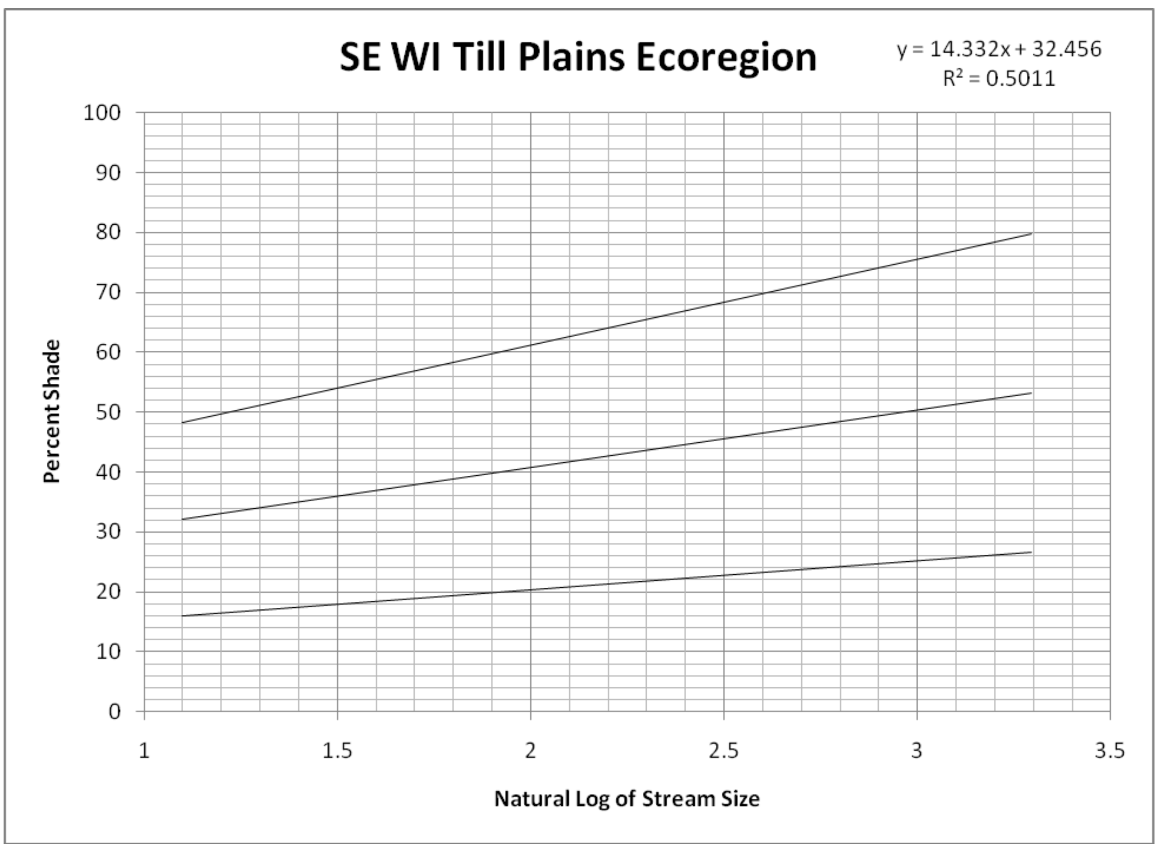
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



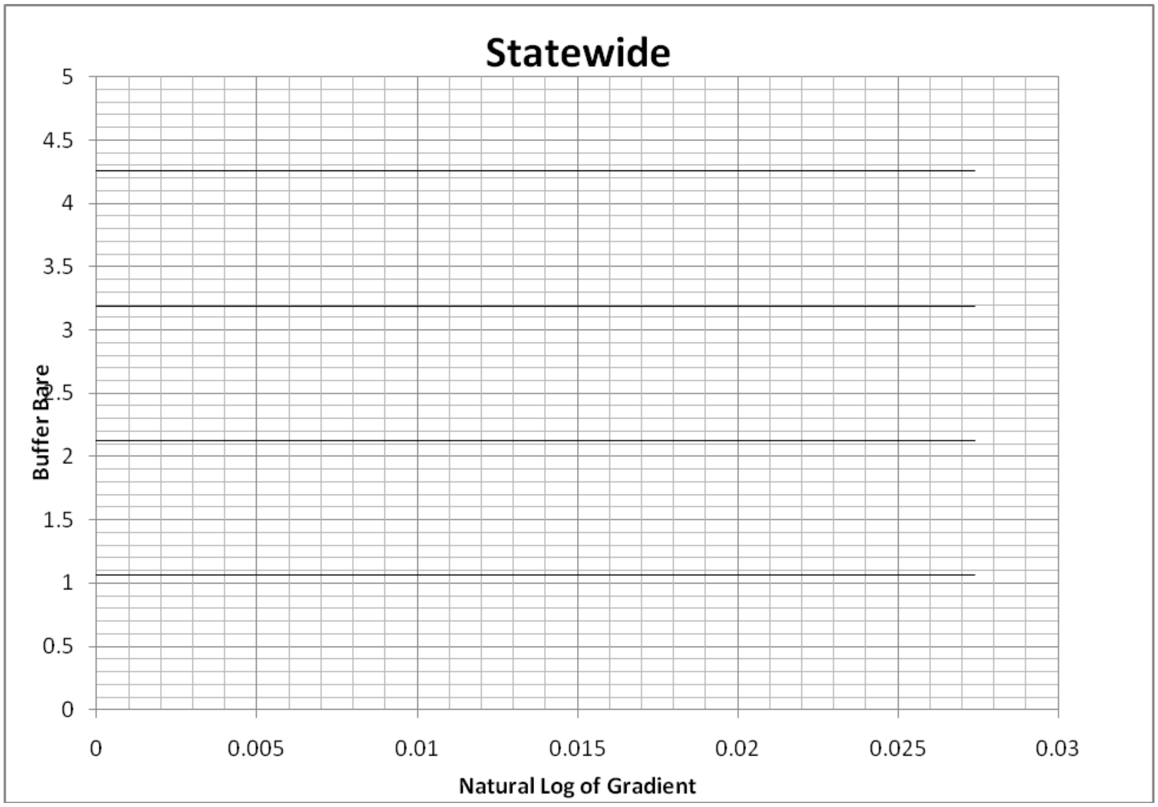


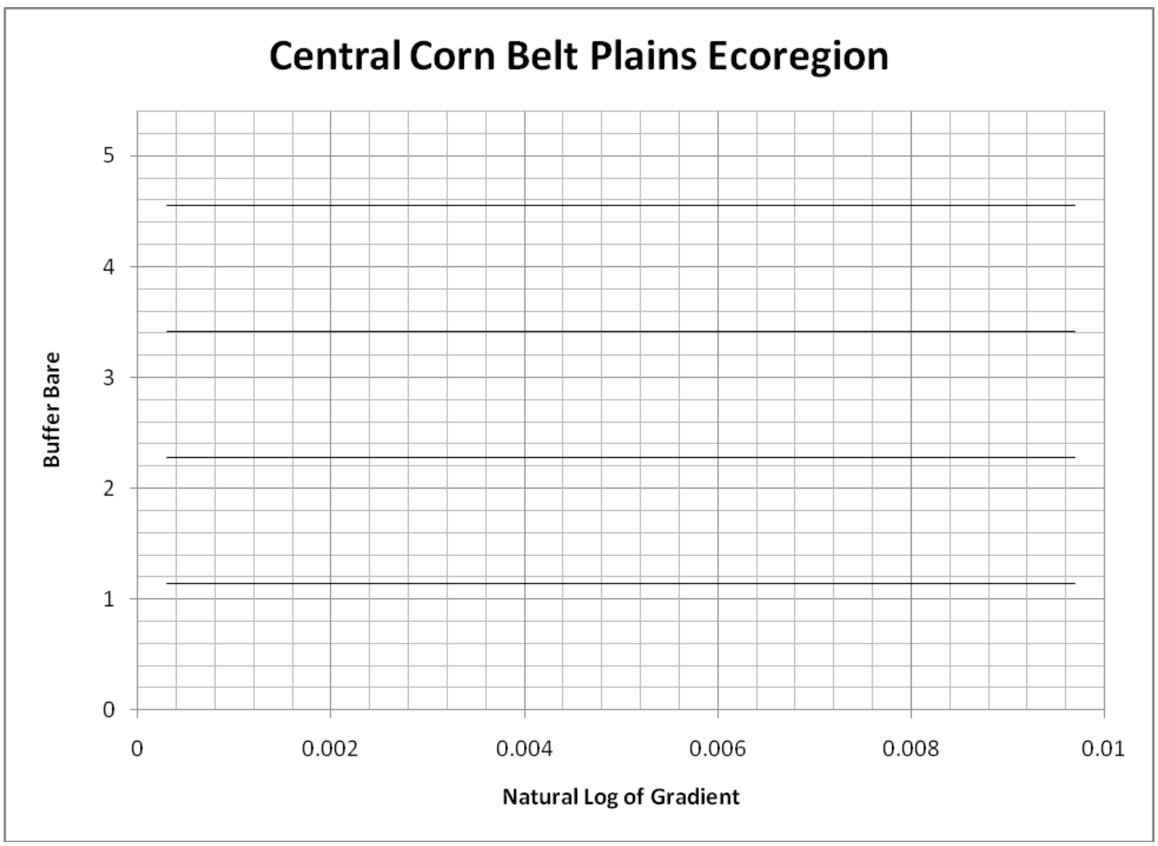
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.





Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.





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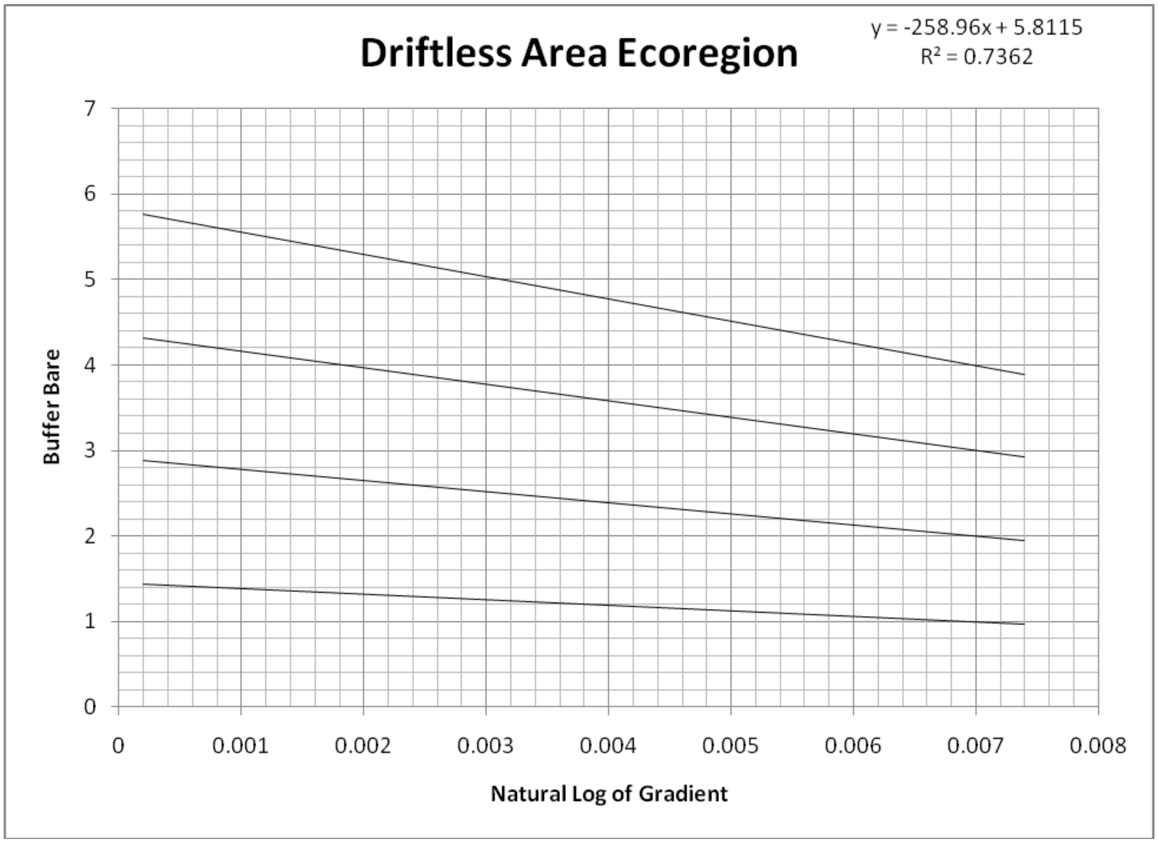

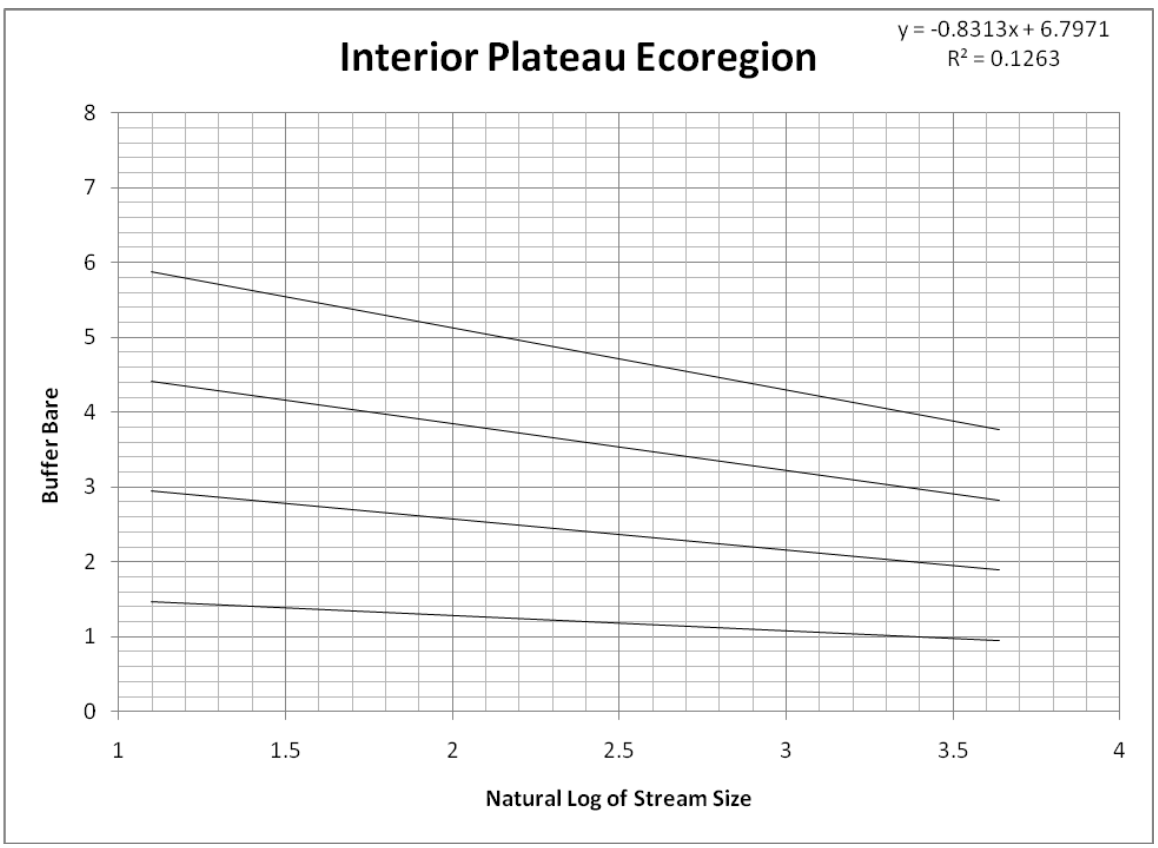

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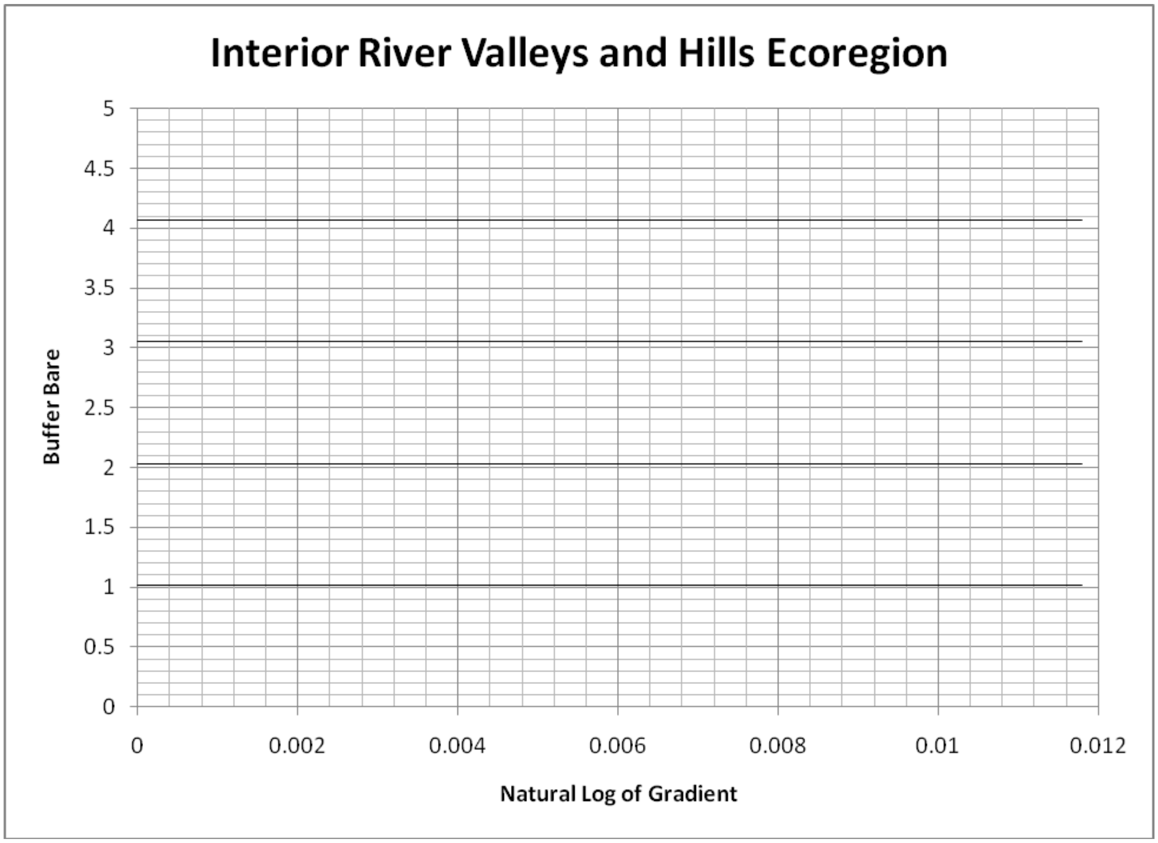
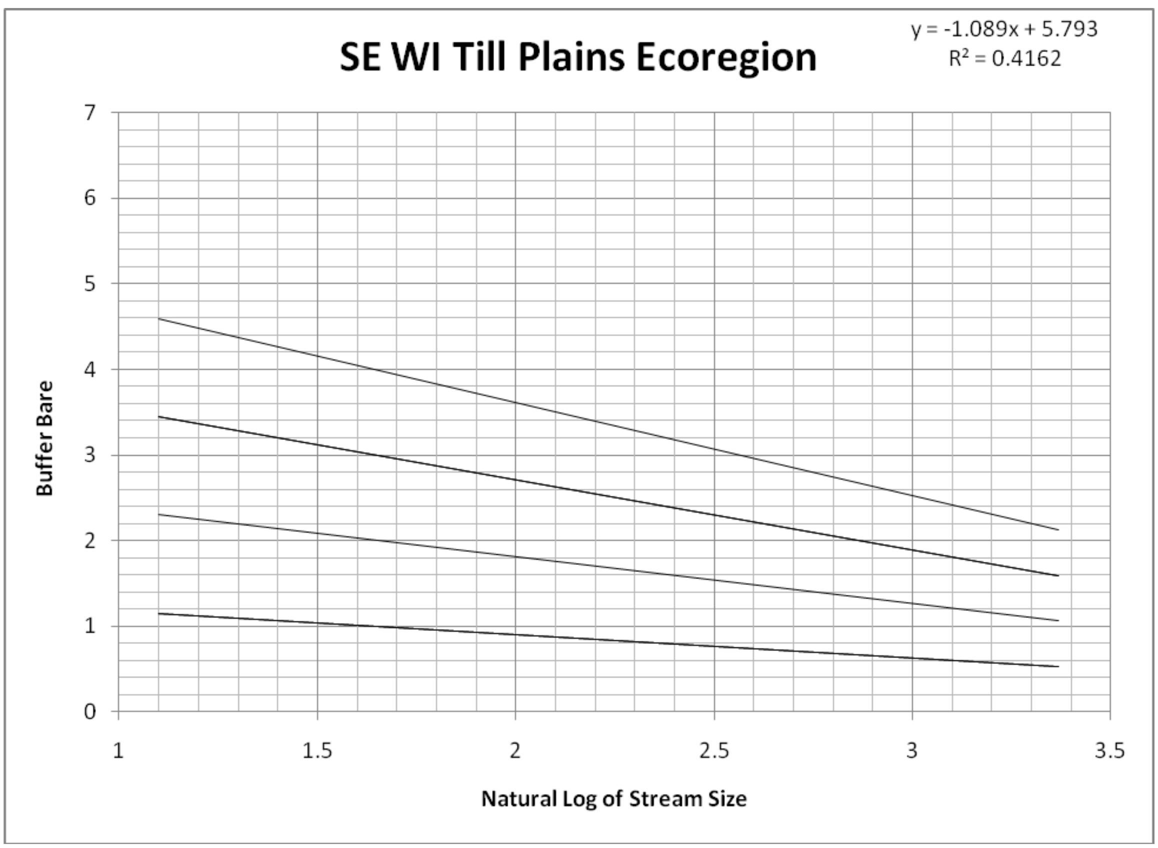
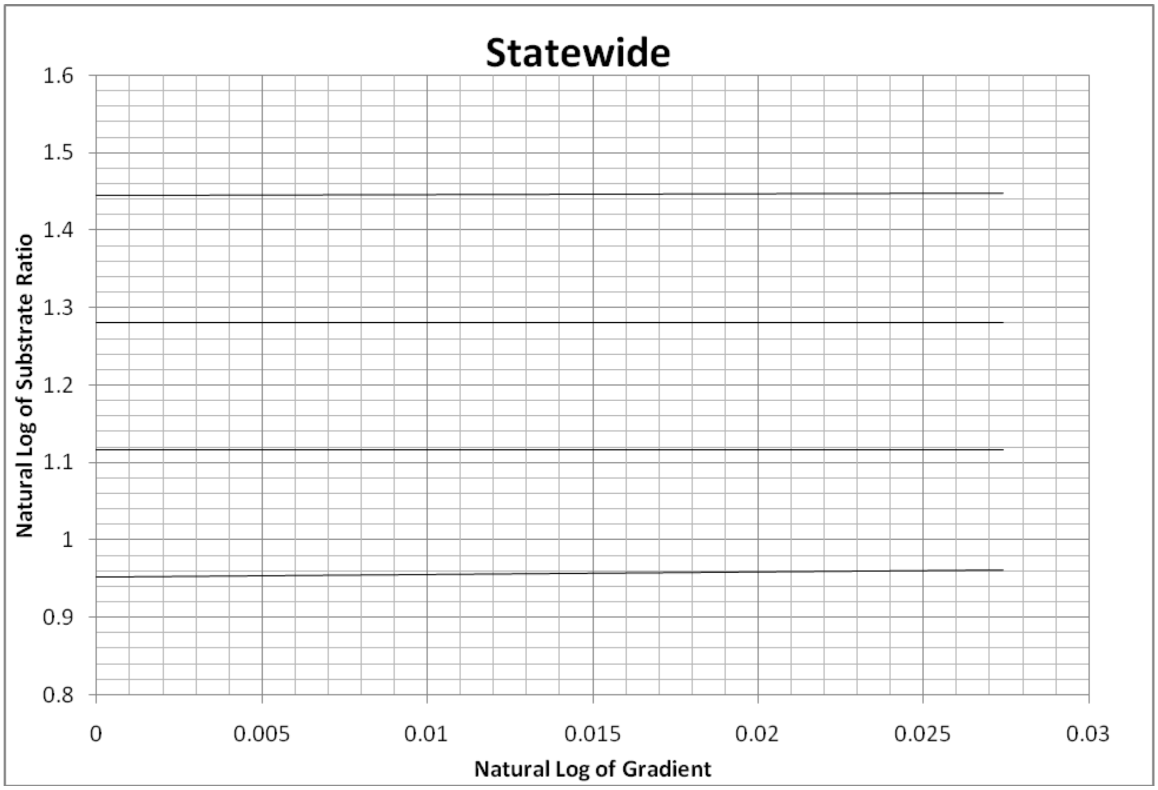
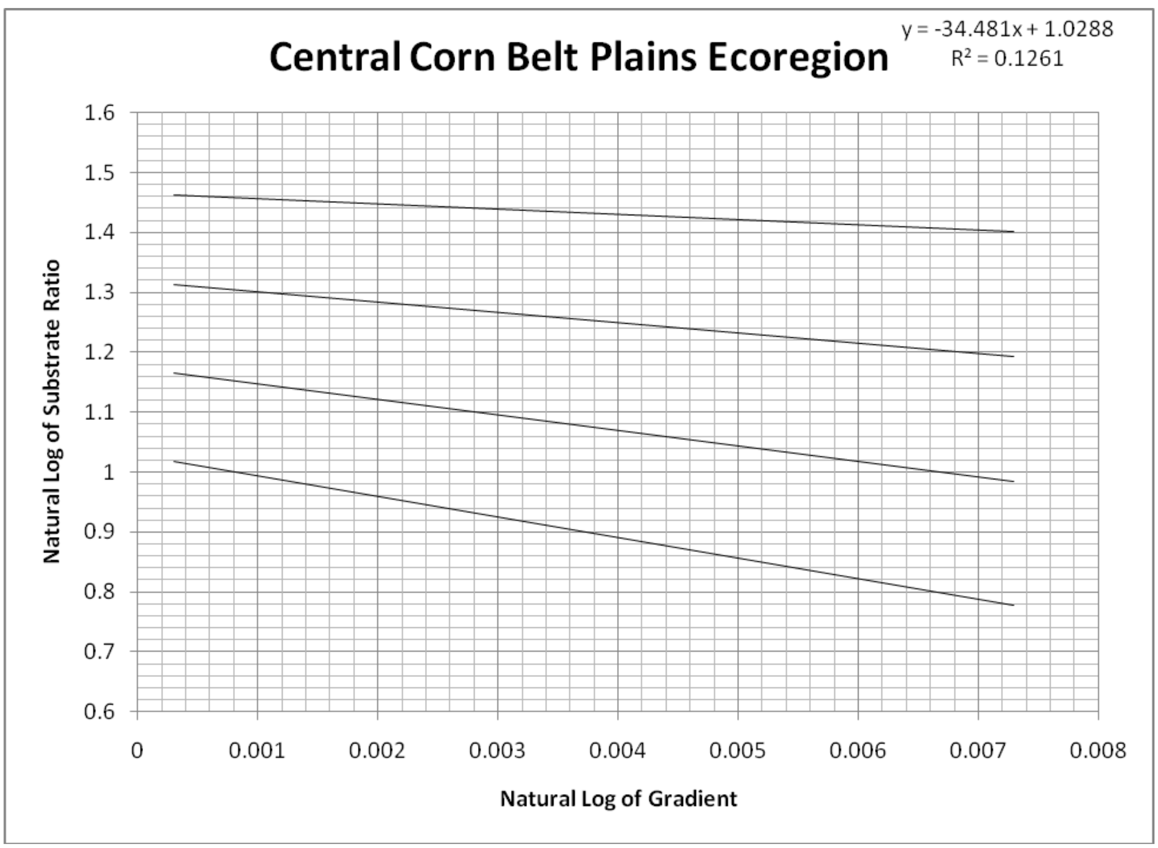




Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.





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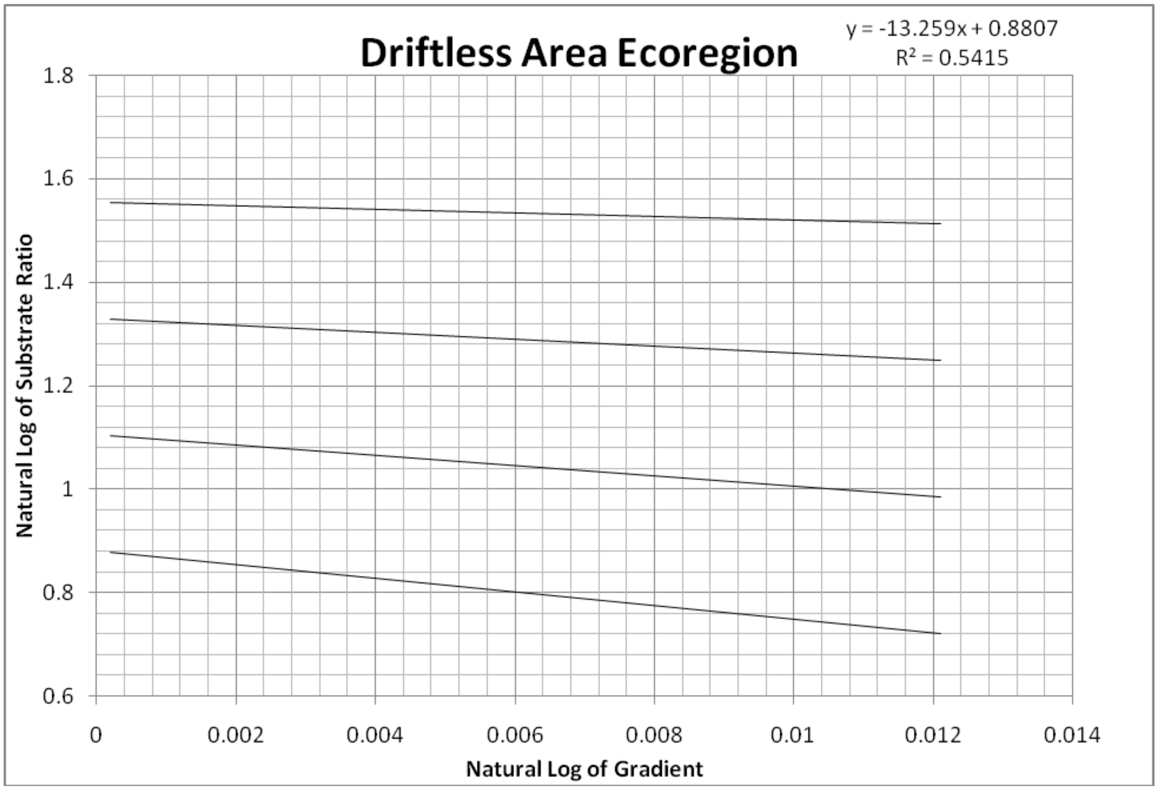
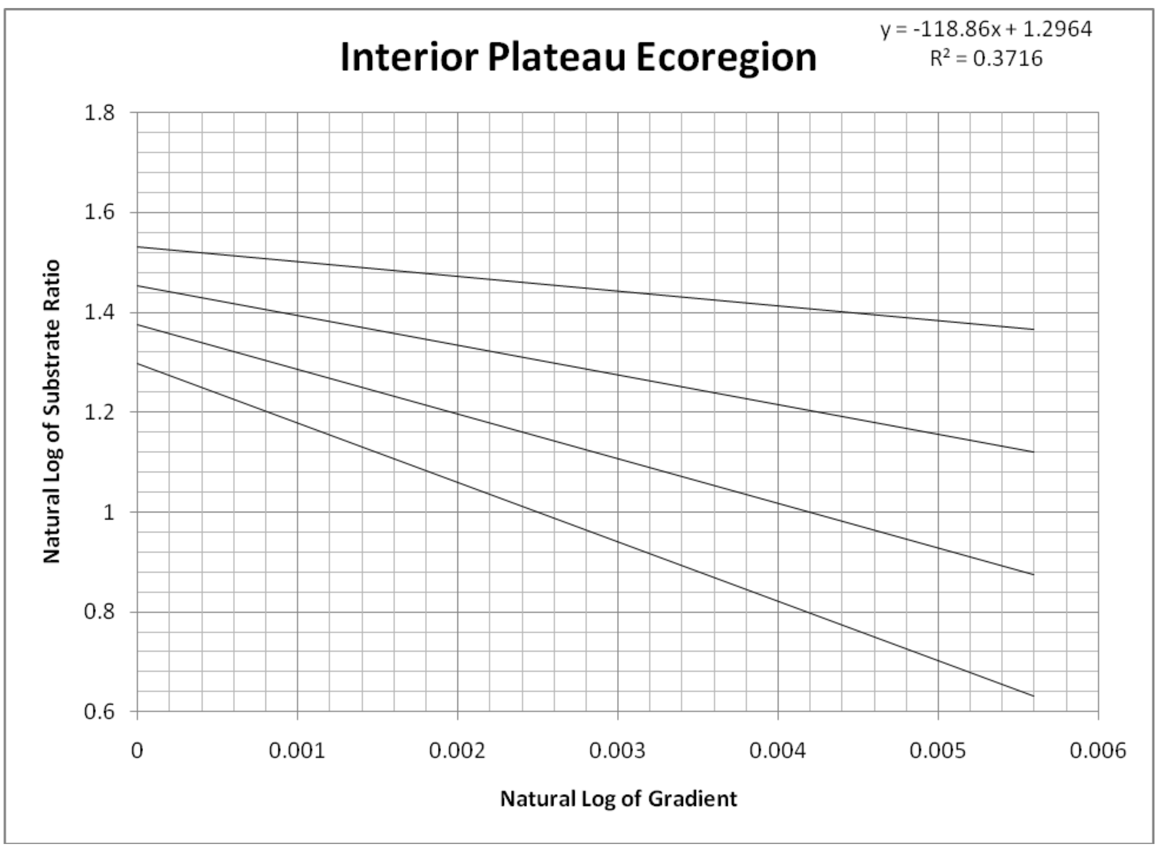
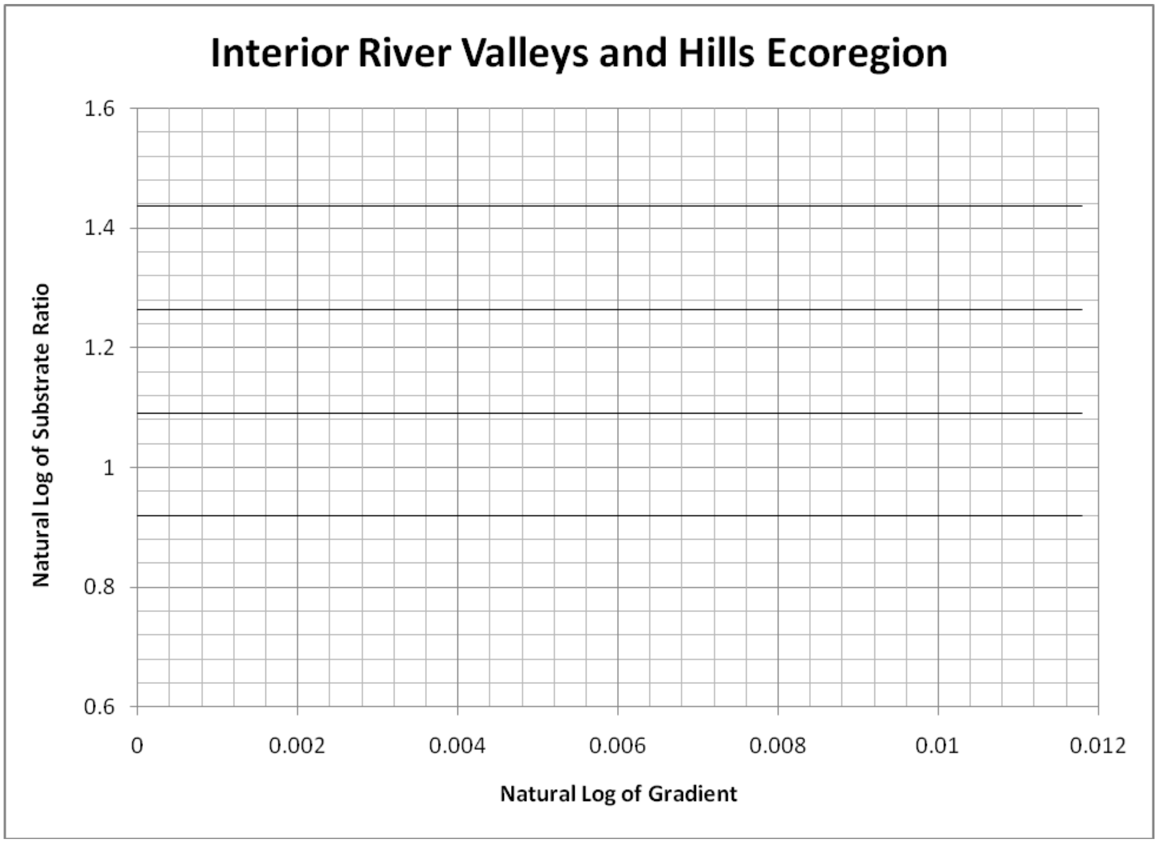
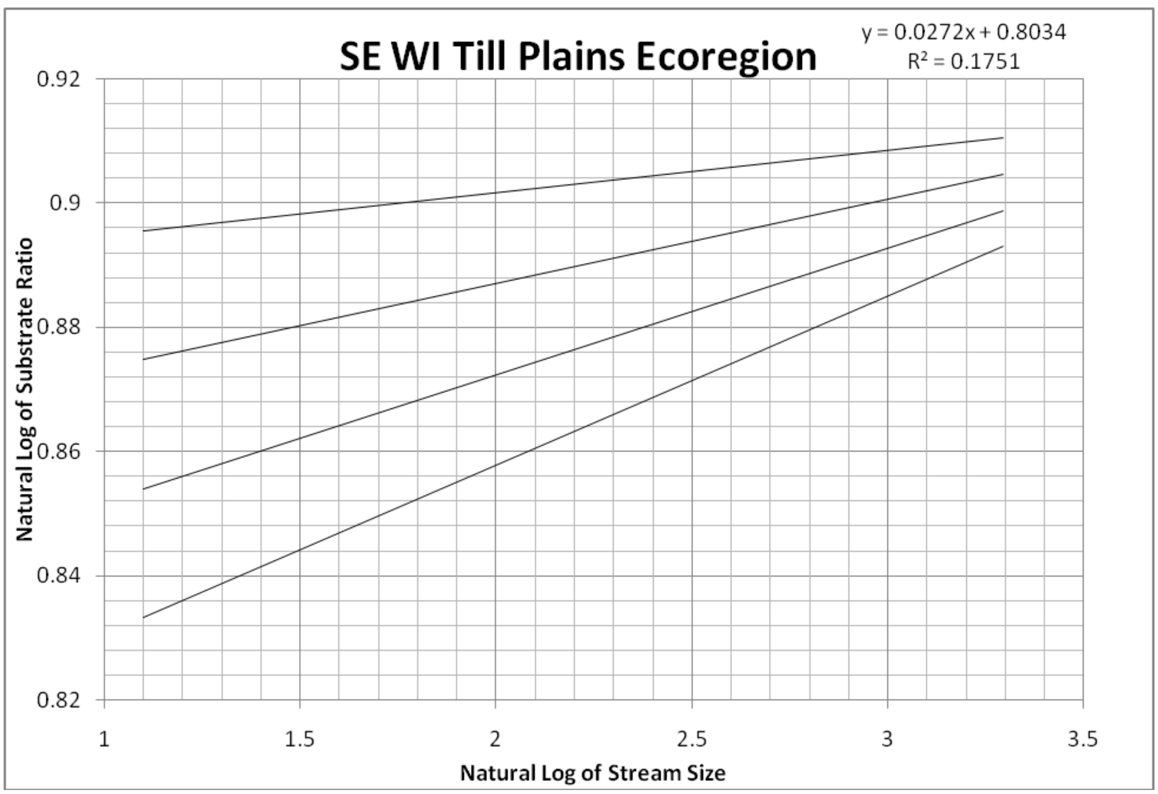


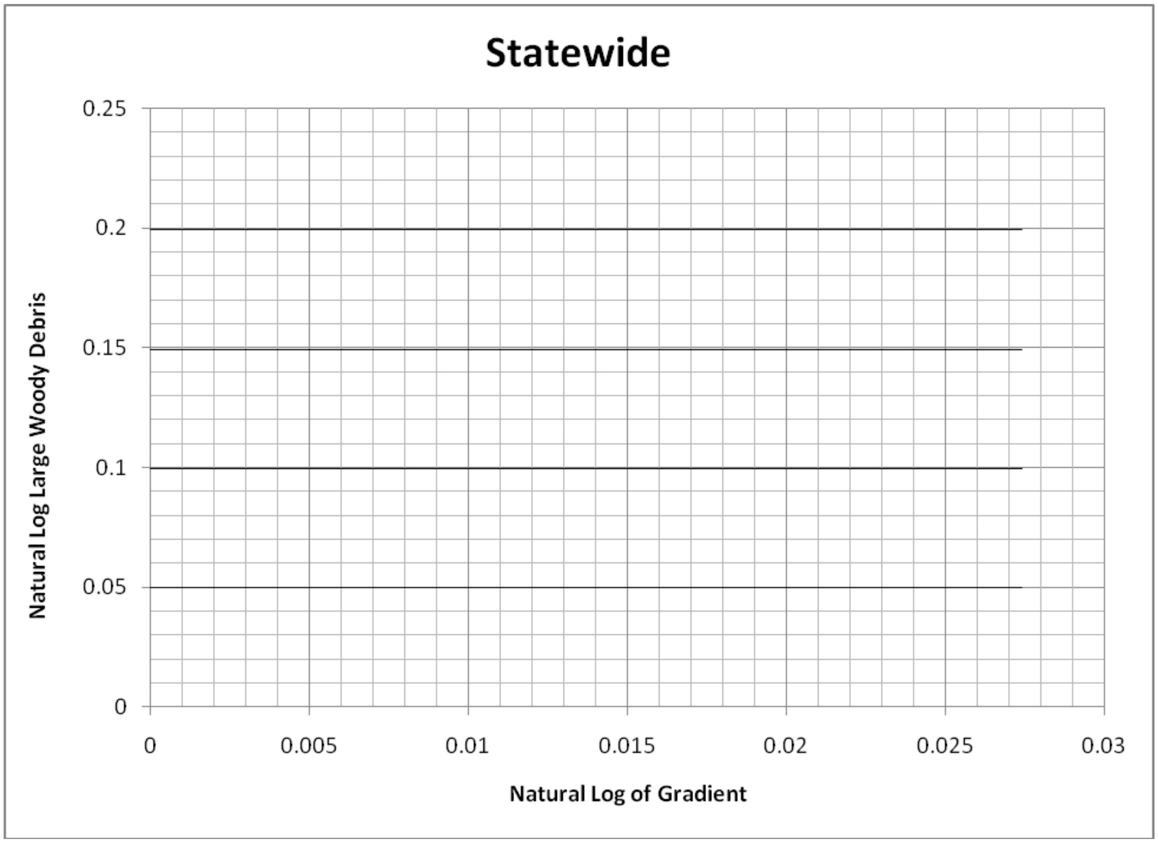


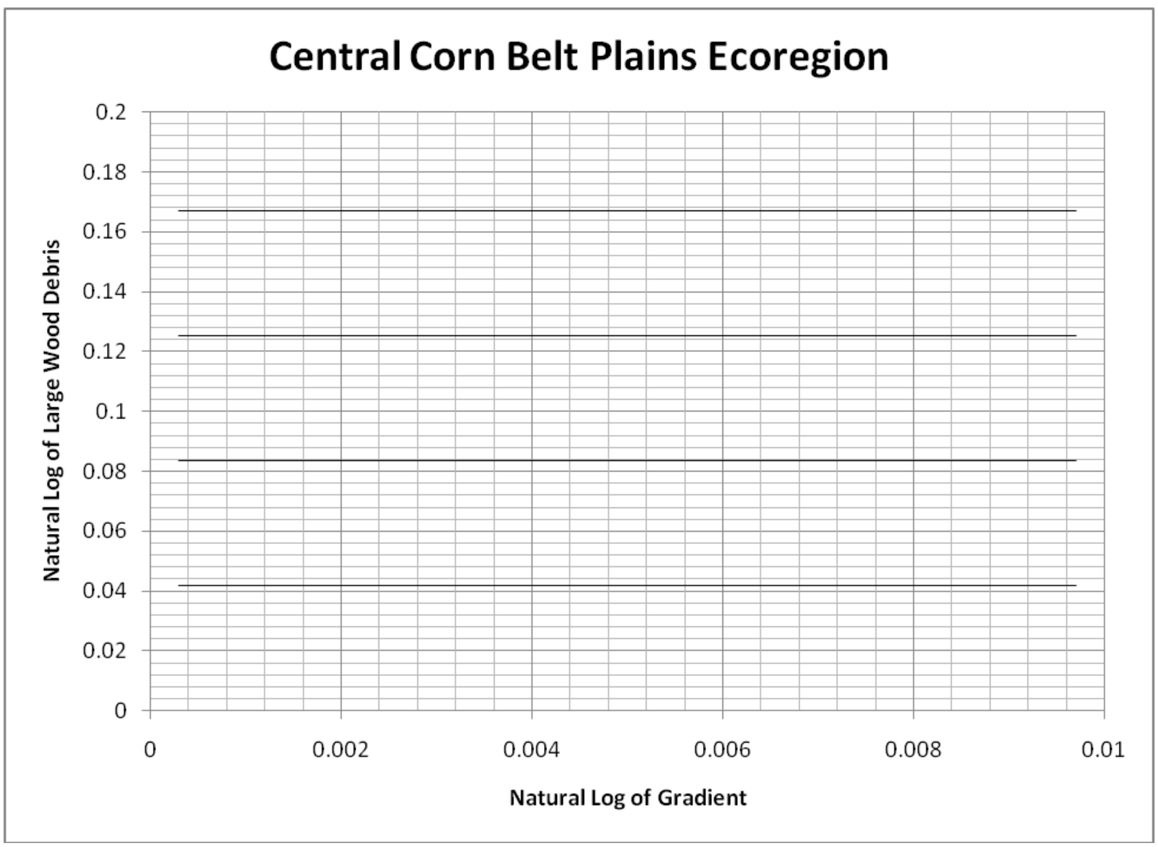
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



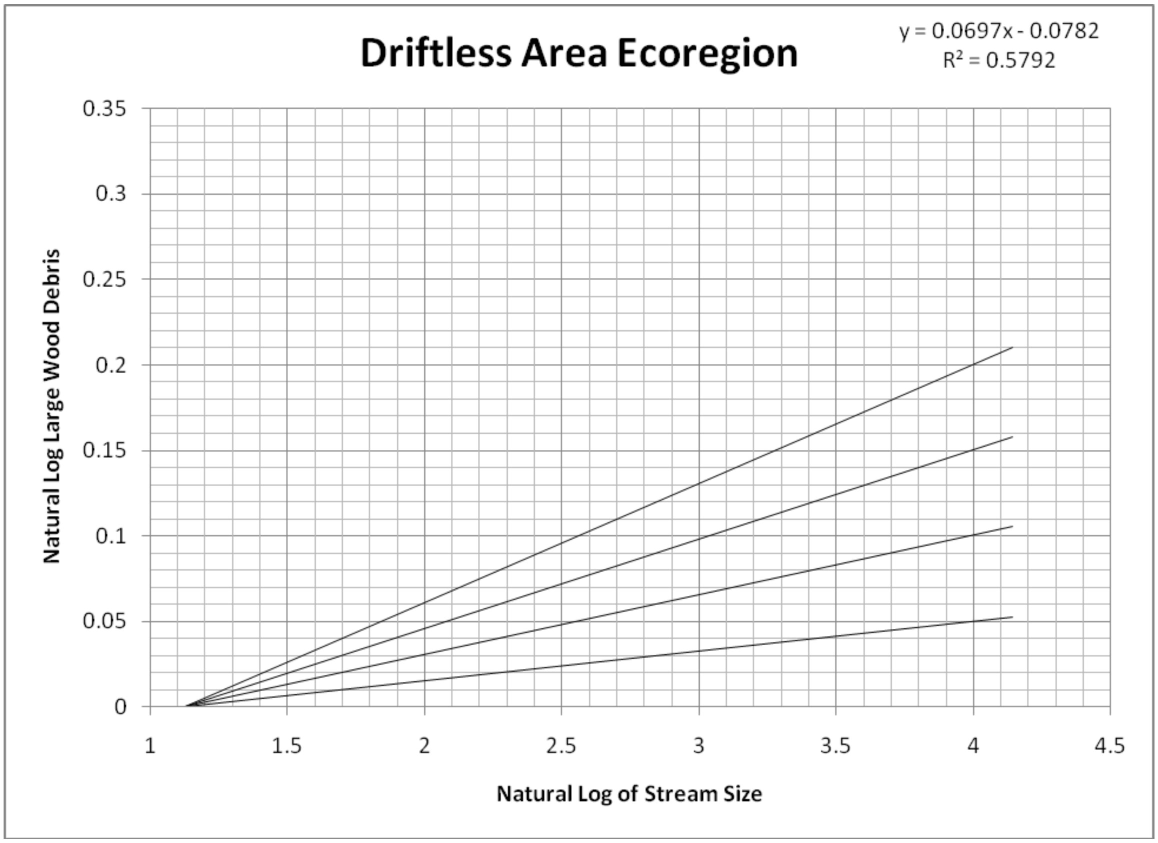


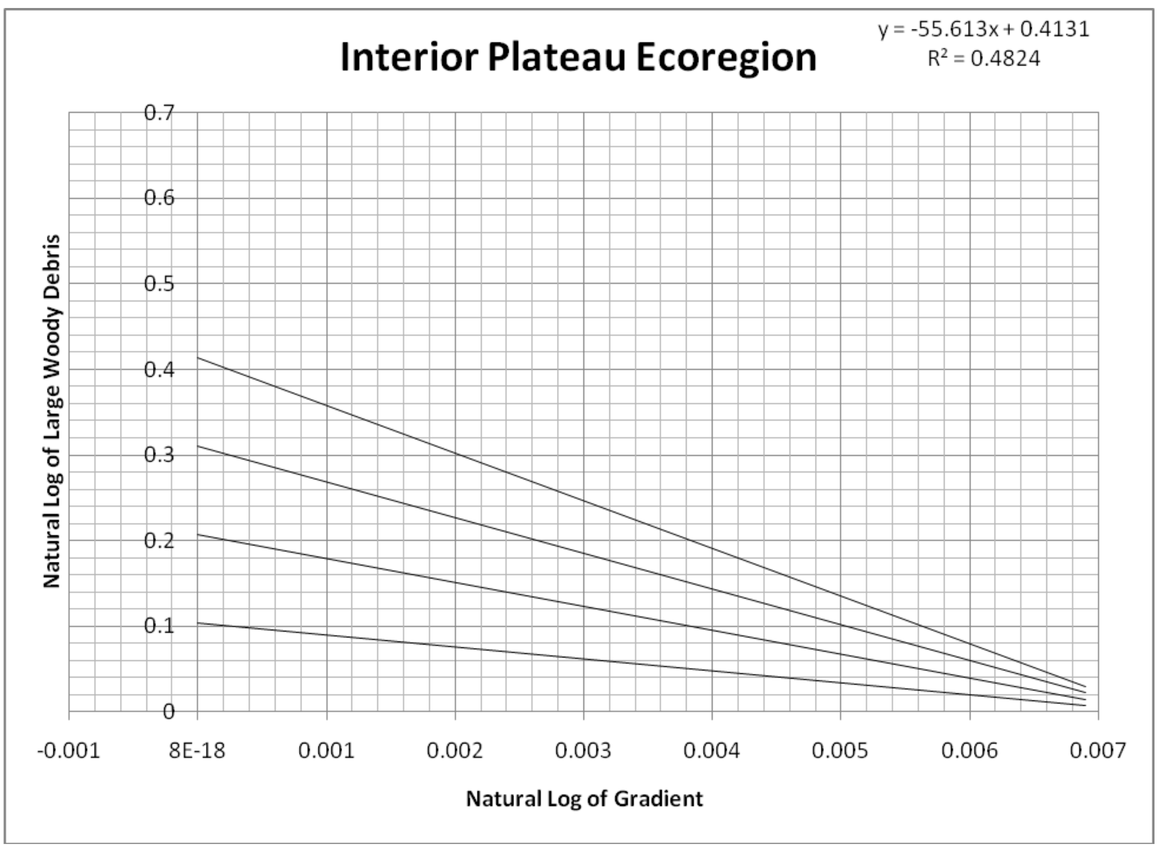
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



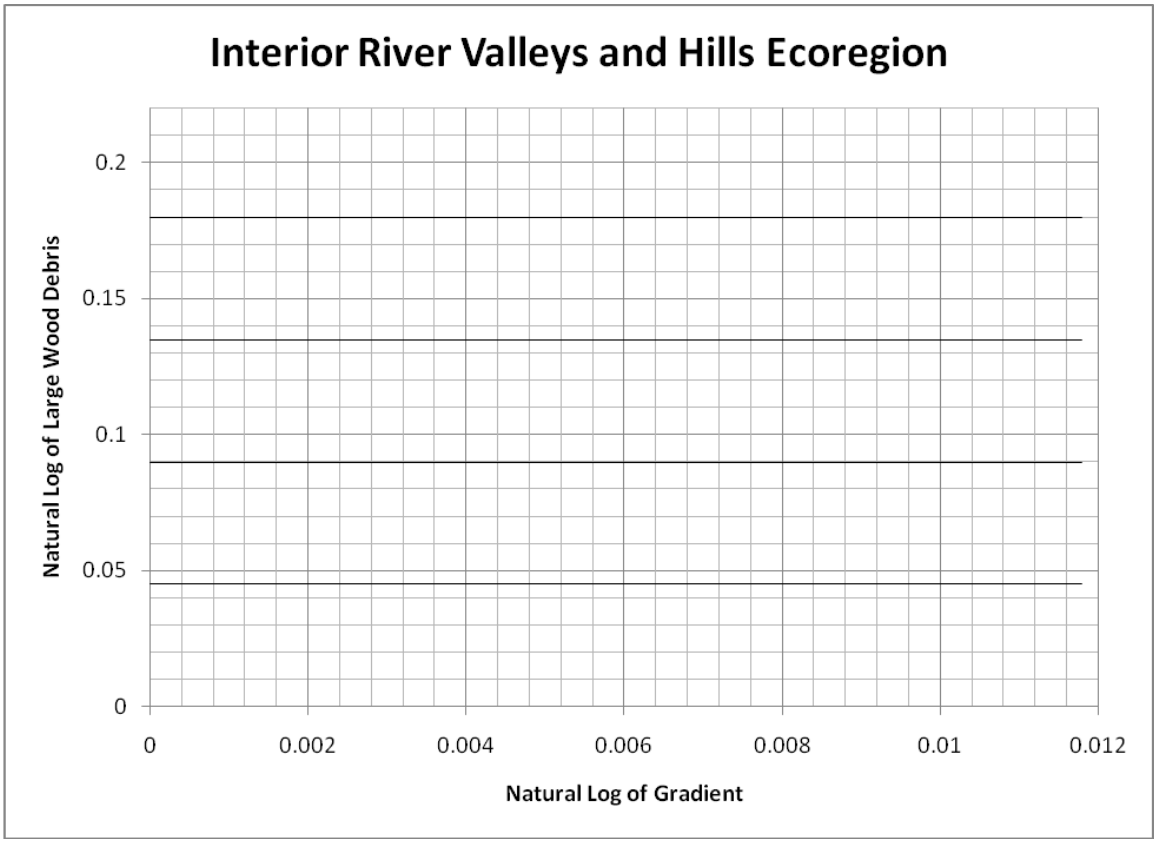


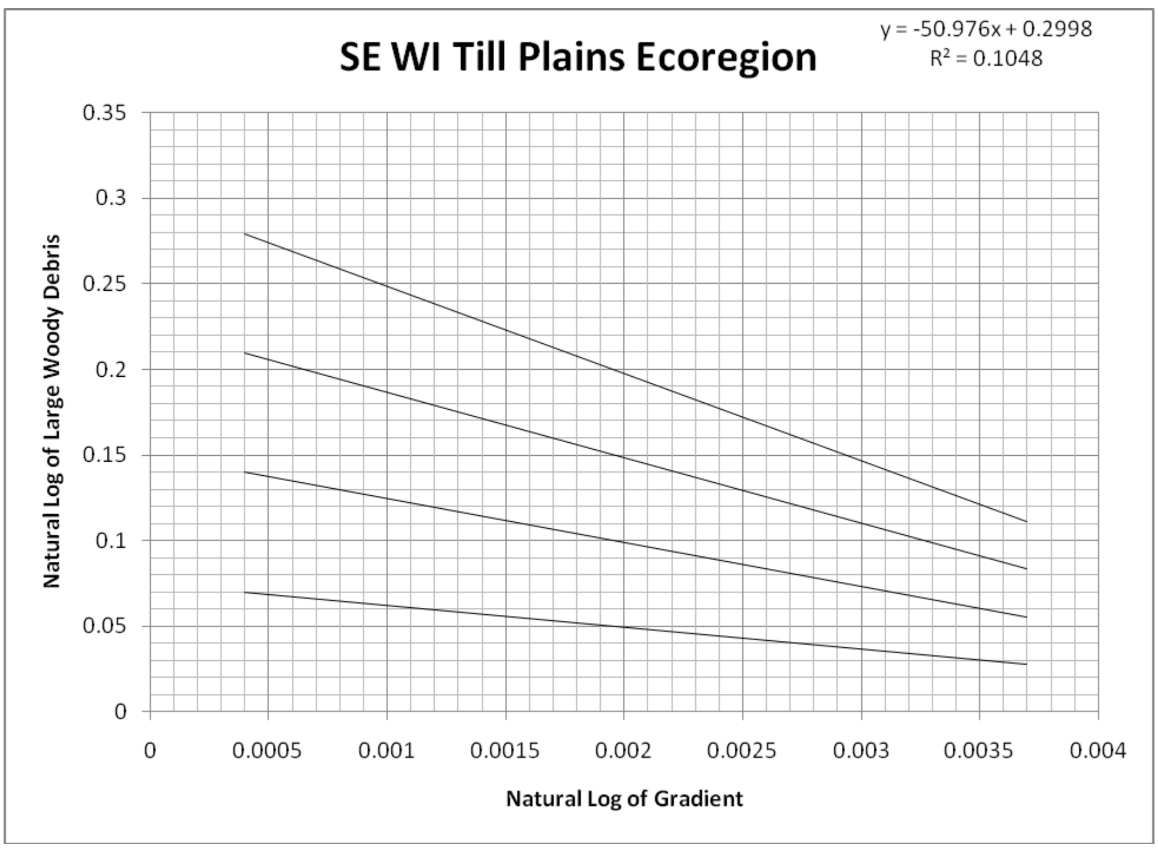
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



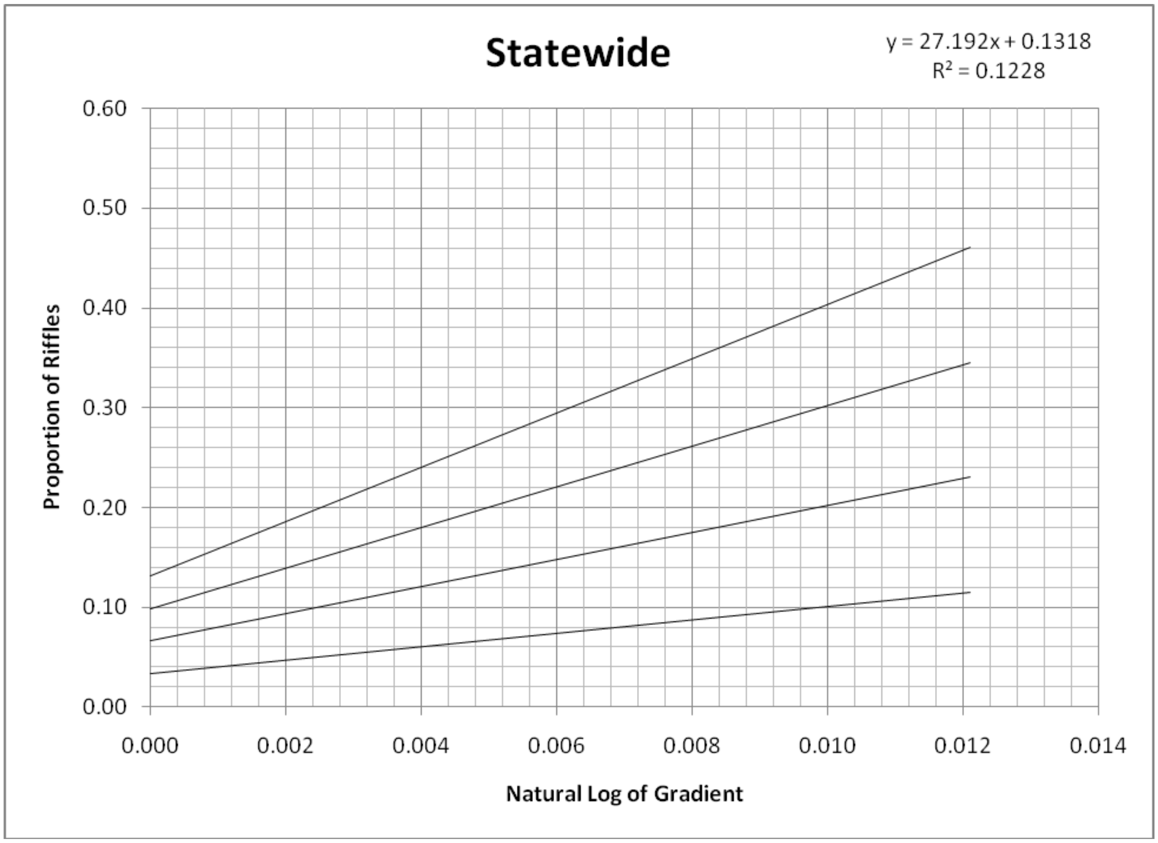


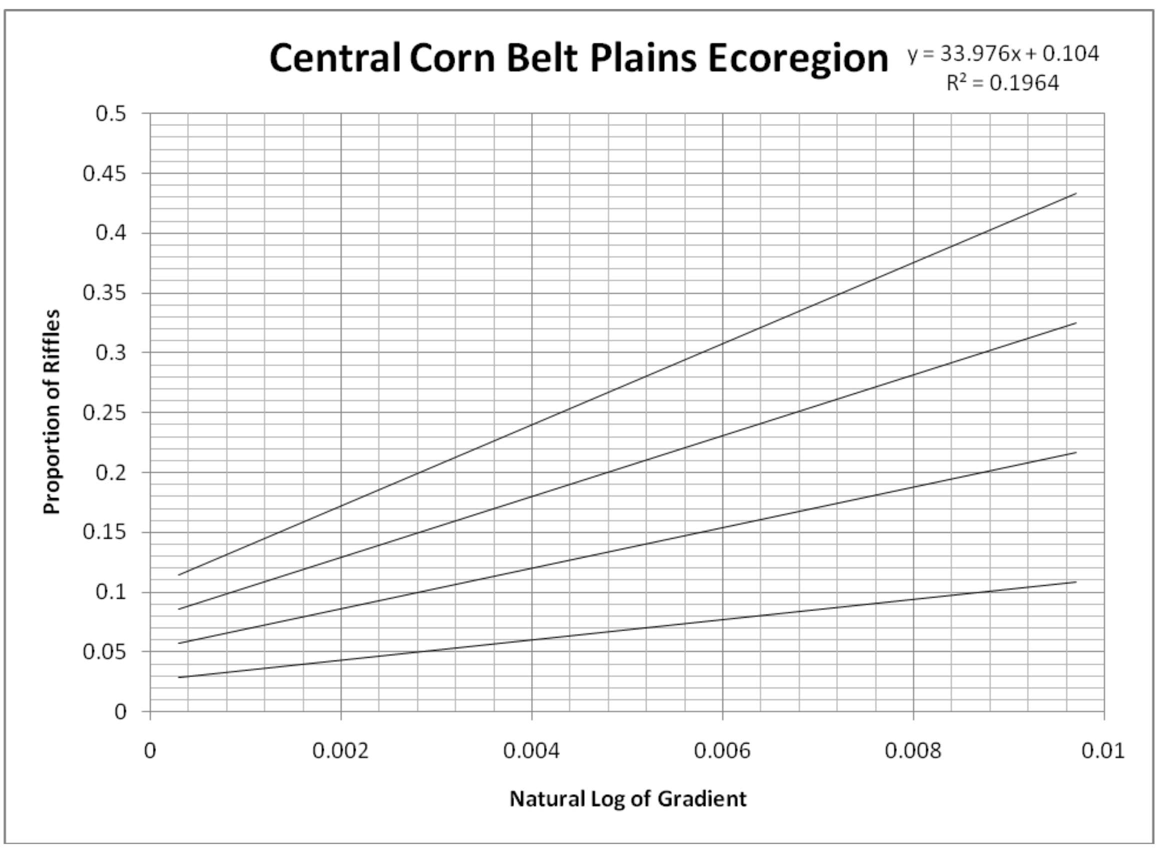
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



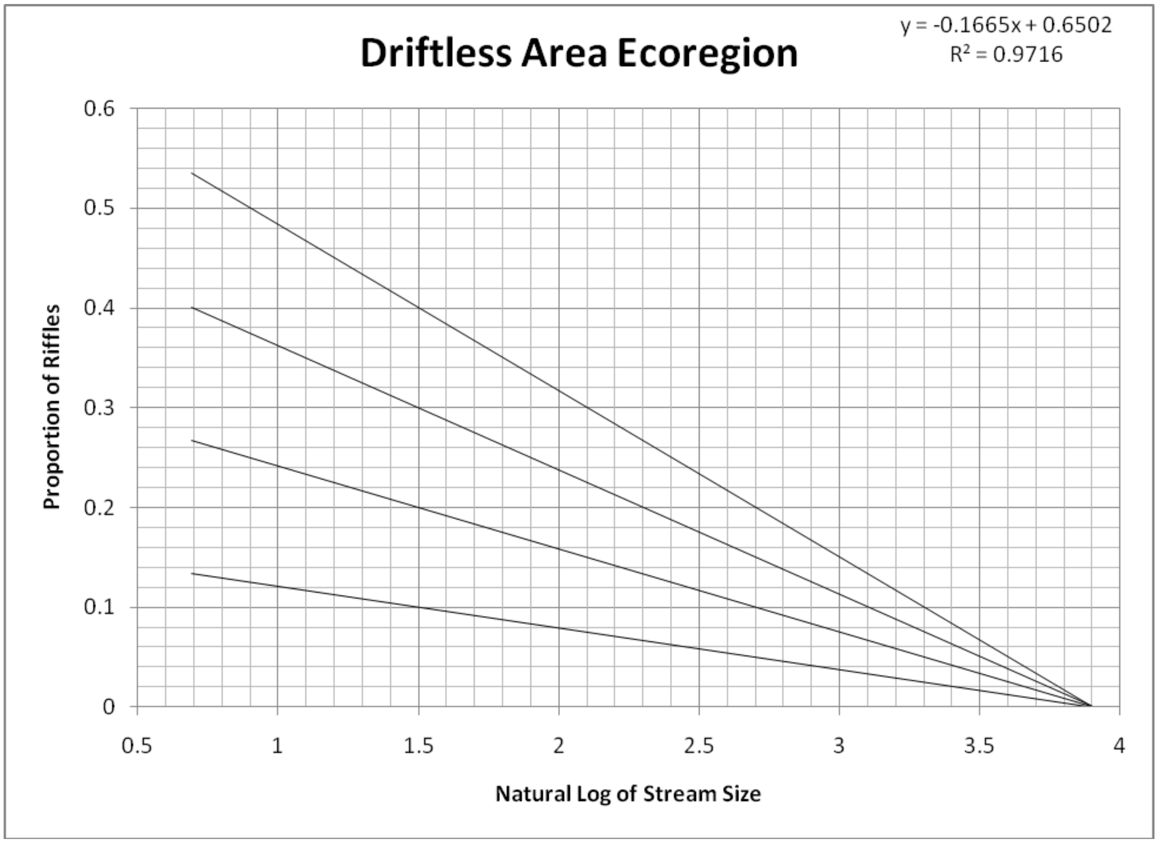


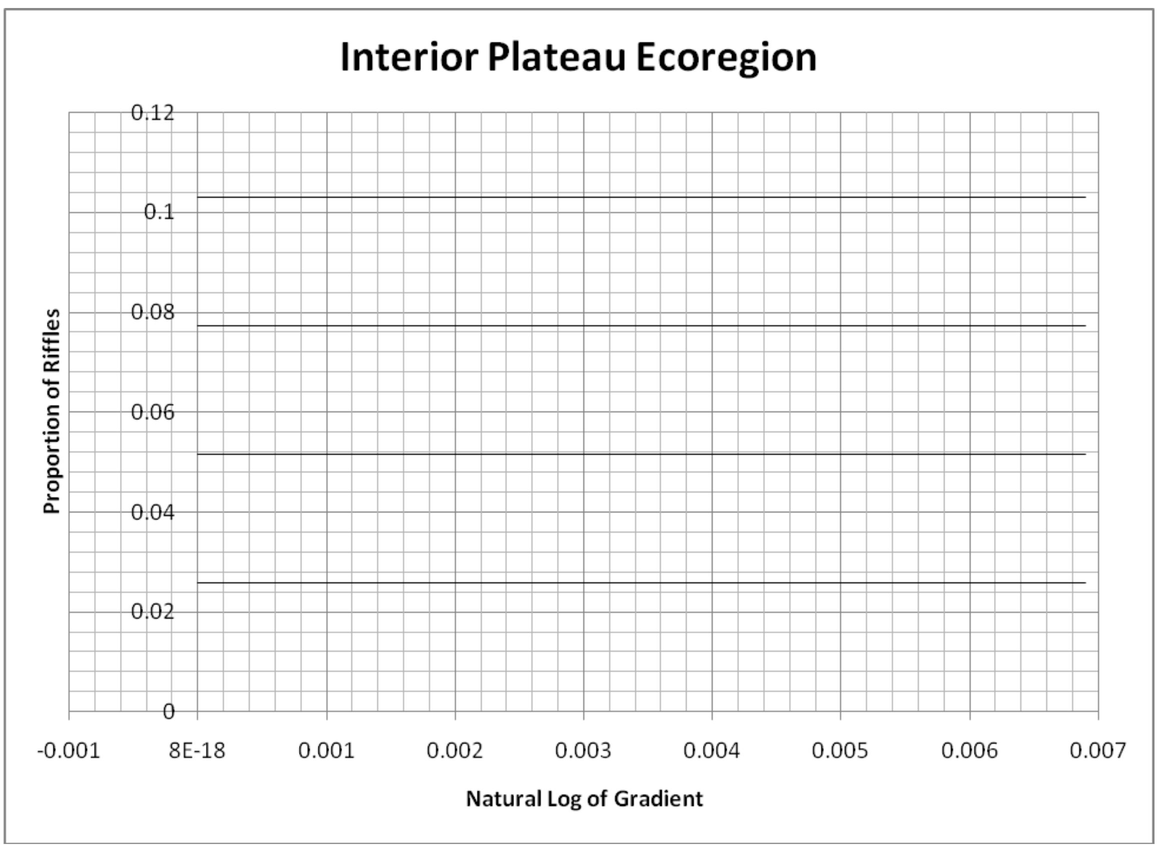
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.



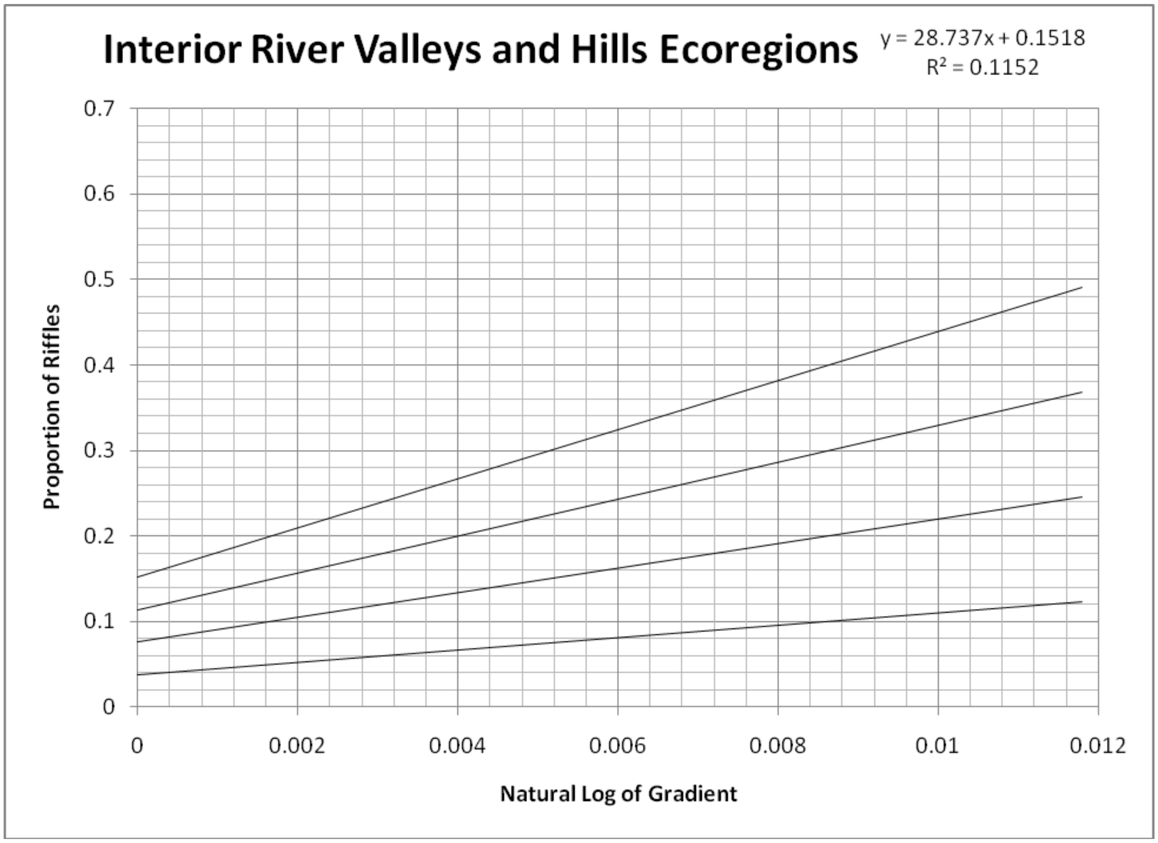


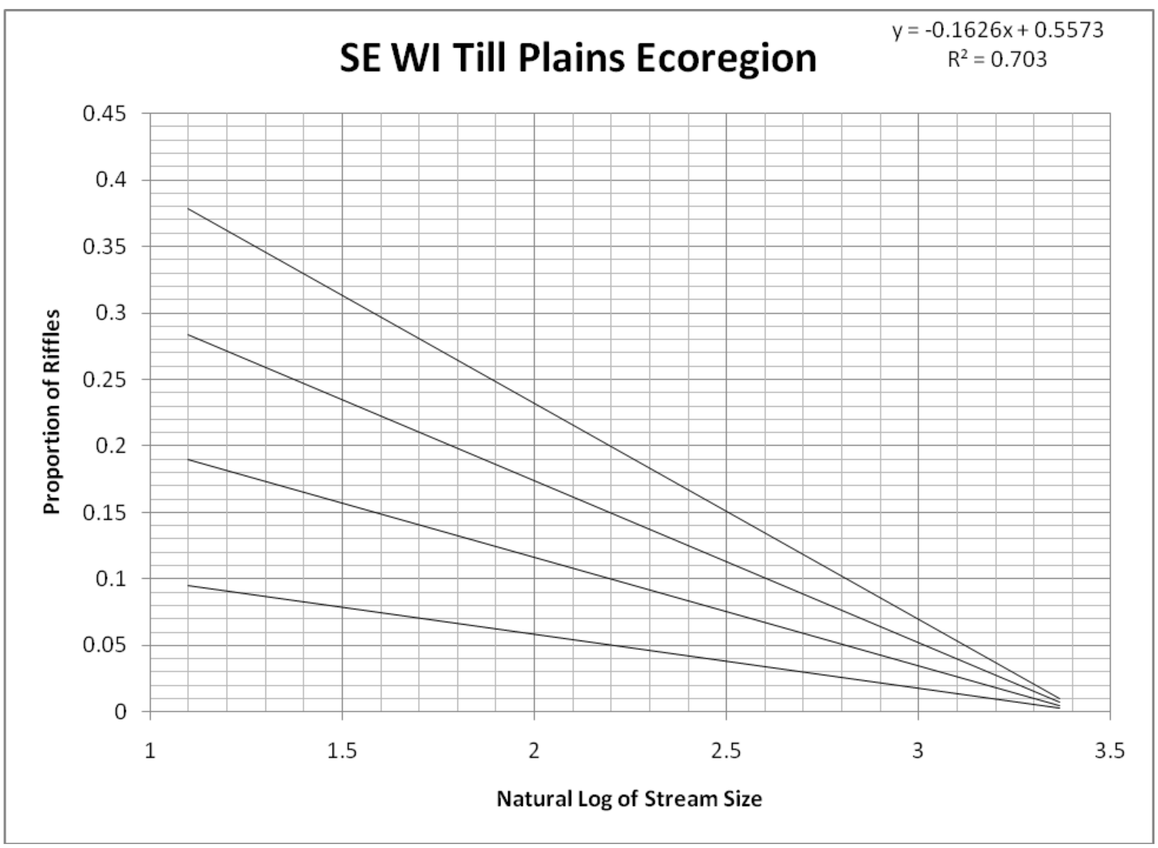
Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.





Appendix C cont. Statewide and Regional Scoring Plots for the Illinois Habitat Index.





Appendix D. Procedure for Physical Habitat Measurements and Scoring of the Illinois Habitat Index.

Procedure for Physical Habitat Measurements and Scoring of the Illinois Habitat Index

Introduction

This document provides a summary of the methods needed to conduct a general evaluation to score the Illinois Habitat Index (IHI). The included site evaluation form at the end of this document is to be used to collect the field data needed to calculate the IHI score. The following protocol should be used to complete the site evaluation form.

General information

Stream: The official name of the stream may be found in the Illinois Atlas & Gazetteer (DeLorme 2003) or in ESRI ArcMap data layer (NHD Streams). If these two sources do not match, list both names for the stream on the data sheet.

IEPA Station Code: At many sites, official Illinois Environmental Protection Agency (IEPA) station codes have been assigned. If no stream code has been assigned, one can be requested from the IEPA by providing GPS coordinates, stream name, and text description of the location.

Scorer: If the forms have not been previously filled out by the scorer, include their full name and contact info in the comments section.

Location Information: Accurate location information is essential. Always enter an exact, very descriptive location on every scorer's datasheet including the name of the county, the gazetteer page number and coordinates, the road that crosses the stream, the closest city in the gazetteer, and the direction from that city. This information is especially important when the stream code is unknown. This will prevent any "orphans" at the end of the season.

Fill out the site and location information for all sites visited. If a site is not sampled, explain in the comments why it was not sampled (e.g., "stream is flooded, will visit later" or "stream is too large, no subsequent visit is necessary").

Latitude/Longitude: Set your GPS to record in NAD83, Lambert. GPS and all location information should be written on the datasheet in addition to the IEPA code.

Reach Characteristics

The access point to the sample reach will most often be a road crossing; the assessment should be made while walking upstream from the road crossing (access point) unless something prevents upstream assessment or it is known that coordinated sampling is conducted downstream of the access point. Assessment should not include effects of the road crossing on the physical habitat of the stream reach. Scorers should walk upstream from the bridge until bridge effects are not apparent (rarely more than 30 m) to start the sampling reach. If no apparent differences are seen, the sample reach should be started 10 m upstream of the access point. Record the distance from the access point at which the sample reach starts and circle whether this is upstream or downstream. Take all measurements in 1/10 m (e.g., 1.5 m) except depth, which should be measured to the 1/100 m (e.g., 0.86 m).

A representative stream reach is determined by sampling a reach length of 20 times the average wetted width. A minimum of 100 m and a maximum of 300 m should be surveyed to evaluate stream characteristics and habitat quality. Total reach length is determined by measuring the wetted width at the beginning of the sample (i.e., 10 m upstream of the bridge) then walking upstream 10 x that distance, at which point the middle wetted width is taken. Scorers should walk 10 x the middle wetted width and then to the end of the current channel unit to obtain the total reach length. If no end to the channel unit is in sight (e.g., the reach is a channelized ditch), total reach length is ended at 20 x the average wetted width. Don’t forget to measure the thalweg depth at the downstream, middle and upstream points as well. Thalweg is defined as the deepest depth in the stream cross-section. Width and thalweg measurements should be taken in areas that appear representative to the stream reach. (i.e., avoid areas that are extra wide or extra narrow compared to the rest of the reach).

Collecting information to score metrics

The Illinois Habitat Index (IHI) is designed to provide a qualitative evaluation of the general characteristics of physical habitat and response to human degradation in the upstream and local watershed. The IHI is composed of five metrics, and each are described herein. Each metric is scored and then all five are summed for the total IHI score. The maximum possible score is 24; the score increases with better quality habitat. Methods for data collection are described, how to score each metric, and how to combine them for the final IHI score. Standardized collection of the data is essential for assigning an accurate IHI score. Scores are encouraged to consult each other to ensure similar scoring approaches.

Metric 1: Buffer_bare

This metric is the sum of the **Average Buffer** code and **Bare:** the average measure for the amount of bare soil visible on the stream banks. The metric value can range from 0-9.

Buffer width is the area adjacent to a stream that is not developed or disturbed (i.e., without human perturbation). A coarsely mowed buffer between an agricultural field (but not a field road) and a stream is ok, but a manicured lawn is not a buffer. Mark only one box with an X for each bank (Left and right, looking upstream). The two boxes checked are given a code and the two measures are averaged for **Average Buffer**. Bare Stream Bank is a measure of the amount of bare soil exposed on each stream bank. The two boxes checked on the Habitat Evaluation Form are given a score and the two scores are averaged for the measure of **Bare**.

Buffer measure	Code
Very Wide > 100m	5
Wide 50-100m	4
Moderate 10-50m	3
Narrow 5-10m	2
Very narrow 1-5m	1
None <1m	0

Bank measure	Measure
None	0
Sparse	1
Intermediate	2
Abundant	3

BB = [(Buffer L + Buffer R)/2] - [(Bank L + Bank R)/2] +3

Metric 2: Substrate Ratio

This metric is the natural log of the ratio of the larger of the two substrate codes to the smaller plus one.

Substrate in Reach denotes the primary and secondary dominant substrates for each reach. Substrate types and size categories that were used are defined in the IEPA Quality Assurance and Field Methods Manual, Section E (IEPA 1994).

Substrate Size Categories:

Substrate	Particle size	Code
Bedrock	Solid rock, large flat slabs of rock not separate from the bottom of the stream	10
Silt	<0.062 mm	1
Sand	0.062-2 mm	4
Fine Gravel	2-8 mm	5
Gravel	8-64 mm	6
Cobble	64-256 mm	7

Boulder	>256 mm	9
Slab Boulder	Relatively flat with longest measurement >256 mm	8
Clay	Material that adheres to itself when squished through your fingers	3
Hardpan	Soil that is compacted to a hardened impermeable layer; it often feels slick and is associated with streams that have clay in them.	3

SR =ln ([larger dominate substrate code/smaller dominate substrate code] + 1)

Metric 3: Percent Shade

This metric describes the amount of shading the water in the stream receives during the hours between 10 a.m. and 2 p.m. Scorers should check the appropriate box, and then assign the percent shade to the metric based on the table below.

Description	Percent Shade **(PS)**
Water surface completely shaded	100
Water mostly shaded with some sunlight	75
Half water surface shaded, half full sunlight	50
Most water surface receiving sunlight	25
Lack of canopy; full sunlight reaching water	0

Metric 4: Proportion of Riffles

As the scorer is walking back to the access point, each channel unit should be noted on the data sheet as a riffle or other. Proportion of riffles is calculated by dividing the number of riffles in the reach by the total number of channel units.

PR = (number of riffle units/number of total units)

Metric 5: Proportion of Large Woody Debris

Amount of large woody debris and aggregate wood in each unit should be indicated for each channel unit as none (0), sparse (1), intermediate (2), or abundant (3).

Proportion of large woody debris is calculated using only the channel units marked as "other". The scores of large woody debris and aggregate woody debris are summed (range for the reach is {[0-6]*# of non-riffle units}). The metric value is calculated as:

LWD = ln ([sum of scores for non-riffle units]/[number of non-riffle units*6]+1)

Scoring the IHI

The IHI Score is the sum of the metric scores for the five metrics. Metrics are scored using x-y graphs specific to each ecoregion. For sites in Illinois that are not located in an area with ecoregion specific graphs the Statewide scoring graphs should be used. To score each metric, locate the x-y graph for that metric in that ecoregion (Appendix C). Plot the metric measure against the appropriate covariate (value labeling the x-axis). Your metric is given the score coordinating to the area in which the point falls. Score all five metrics in this manner and sum the five scores for the IHI score.

IHI = Metric Score$_{BB}$ +Metric Score$_{SR}$ + Metric Score$_{PS}$ + Metric Score$_{PR}$ + Metric Score$_{LWD}$

EQUIPTMENT LIST

1. Map of Site Location
2. GPS (NAD83 Lammert Datum)
3. Camera
4. Extra batteries
5. Pencils
6. Habitat Evaluation Forms (printed on rite-in-the-rain paper)
7. Measure Tape (preferably in meters)
8. Depth rods (meter sticks or PVC pipes with depths marked every 1/100 m work well)
9. Waders/water shoes
10. Sun screen
11. First Aid Kit
12. Bug spray

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Appendix D cont. Procedure for Physical Habitat Measurements and Scoring of the Illinois Habitat Index

HABITAT EVALUATION FORM

Page __1__ of _____

	Location Information	
Stream:	County	
	Gaz pg and coord.	
Date:	Latitude	
IEPA	Longitude	
Station Code:	Road crossing	
	Nearest town	
Scorer(s):	Direction	N NE E SE S SW W NW

Notes:

REACH CHARACTERISTICS

Check one box per bank. River right looking upstream.

Buffer Width

L R (Per Bank)

- ☐ ☐ Very Wide > 100m
- ☐ ☐ Wide 50-100m
- ☐ ☐ Moderate 10-50m
- ☐ ☐ Narrow 5-10m
- ☐ ☐ Very narrow 1-5m
- ☐ ☐ None <1m

Bare Stream Bank

L R (Per Bank)

- ☐ ☐ None
- ☐ ☐ Sparse
- ☐ ☐ Intermediate
- ☐ ☐ Abundant

	Wetted Width	**Thalweg Depth**
Downstream	m	m
Middle	m	m
Upstream	m	m
Average	m	m

Reach Length______________m

Number of channel units ________

Reach starts ____m from bridge.

Sampling from bridge is

UPSTREAM

DOWNSTREAM

Substrate in Reach

Mark dominant and next dominant substrates

- ☐ ☐ Boulder (>256 mm)
- ☐ ☐ Slab Boulder (>256 mm)
- ☐ ☐ Cobble (64-256 mm)
- ☐ ☐ Gravel (8-64mm)
- ☐ ☐ Fine Gravel (2-8 mm)
- ☐ ☐ Sand
- ☐ ☐ Clay/Hardpan
- ☐ ☐ Silt
- ☐ ☐ Bedrock

Shading of Water Surface

Mark a total for the reach

- ☐ Water surface completely shaded
- ☐ Water mostly shaded with some sunlight
- ☐ Half water surface shaded, half full sunlight
- ☐ Most water surface receiving sunlight
- ☐ Lack of canopy; full sunlight reaching water

CHANNEL UNIT CHARACTERISTICS

Circle Type: Circle Amount: (0=None, 1=Sparse, 2=Intermediate, 3=Abundant)

1	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
2	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
3	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
4	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
5	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
6	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
7	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
8	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
9	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
10	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
11	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
12	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
13	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
14	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
15	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
16	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
17	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
18	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris
19	Riffle	Other	0 1 2 3 Large Woody Debris	0 1 2 3 Aggregate Woody Debris