Illinois Natural History Survey
Division of Ecology and Conservation Science

(May 1, 2006 - October 30, 2007)

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Evaluating Streams in Illinois based on Aquatic Biodiversity

Final Project Report 2007

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Introduction

Comprehensive statewide biological, chemical, and physical information associated with streams in Illinois has been routinely collected since 1980 through a partnership between the Illinois Department of Natural Resources (IDNR) and the Illinois Environmental Protection Agency (IEPA; Bertrand *et al.* 1996). This partnership was established in order to assess fish and macroinvertebrate communities, water quality, and habitat throughout major basins of Illinois. In 1984, a Biological Stream Characterization (BSC) Work Group was convened to create a mechanism for interpreting data collected as part of the inter-agency basin survey program, and "to provide managers an overall prospective of the state's stream resources" (Hite and Bertrand 1989). The BSC Work Group developed stream ratings using letter grades "A" through "E", thereby establishing a means of communicating the quality of biological resources in streams to diverse stakeholders that are still in use today.

At the time the BSC Work Group began, the fish-based Index of Biotic Integrity (IBI) was recently developed, and it became the predominant stream integrity indicator used for rating streams (Hite and Bertrand 1989). Therefore, the assigned letter ratings for streams were primarily a reflection of the attributes of fish communities. In recognition of the need to also protect other stream-dependent organisms in the state, the Illinois Natural History Survey (INHS) developed a list of Biologically Significant Streams (BSS) that incorporated data on mussel communities and rare species (endangered, threatened, watch list) of crustaceans, fish, mussels, and aquatic plants as well as stream segments rated as "A" by the initial BSC (Page *et al.* 1992). Despite the lack of regular updates, the BSC and BSS processes generated products that are still used extensively by state and federal agencies as well as local watershed groups, consultants, environmental interest groups, and municipalities.

Several purposes of the previous BSC and BSS processes overlapped between the two initiatives. Both had objectives to identify the extent of Illinois stream resources, to identify stream segments of exceptional quality, and to focus protection efforts toward uncommon resources or biologically significant streams (Bertrand *et al.* 1996, Page *et al.* 1992). However, the two initiatives differed in their overall intent to rate a stream's biological diversity (Page *et al.* 1992) or biological integrity (Bertrand *et al.* 1996; Hite and Bertrand 1989). Diversity simply defined is the number of different kinds of things (Angermeier and Karr 1994) or the variety of life and its processes (Hughes and Noss 1992). Biological integrity refers to a system's wholeness (Angermeier and Karr 1994) and the ability to support organisms and processes comparable to natural habitat of the region (Hughes and Noss 1992).

In this report, we rate streams for biological diversity and integrity independently. We also consider all the information that contributed to both these ratings in order to identify Biologically Significant Streams. Although diversity can be represented mathematically using summary indices or a simple species number, we consider it more broadly as the variety of taxa within several important aquatic groups (e.g., mussels, fish, macroinvertebrates, crayfish). Indices or assessment measures like the fish-based IBI (Smogor 2000) measure how closely a test community resembles a natural, least-disturbed, or intact community (see Stoddard *et al.* 2006 for a discussion of these terms.). We include these types of measures in a stream integrity rating. Diversity and integrity ratings are kept separate because it is possible to have highly intact communities that are not biologically very diverse. For instance, species richness expectations for small or cold-water streams are expected to be low compared with larger or warmer streams. Therefore, it is possible to have a small stream that would rate high for integrity but low for diversity. Additionally, keeping the two ratings separate enables stakeholders with different purposes to consider the rating that is most applicable to their needs.

Since BSC and BSS were developed, the quantity and quality of aquatic data and assessment tools has increased. This report describes an approach that combines, updates, and enhances the two previous methods for rating Illinois streams. Our goal in this project was to integrate multiple taxa into an overall rating for stream segments, similar in intent to the "overall prospective" identified by Hite and Bertrand (1989) and in Illinois' Wildlife Action Plan, which broadly addresses multiple taxa. Due to differences in life-history, mobility, and sensitivities to stressors, different taxonomic groups respond dissimilarly to shared stream conditions (Paller 2001). We used fish, macroinvertebrate, and mussel information because these taxa reflect steam conditions at different spatial and temporal scales (Diamond and Serveiss 2001, Freund and Petty 2007, Kilgour and Barton 1999, Lammert and Allan 1999). For instance, due to their limited mobility, typically shorter life spans, and association with stream substrate, macroinvertebrates may be indicators of local and more recent stream conditions (Freund and Petty 2007), whereas fish with their greater movement capabilities and longer life cycles may be better indicators of regional conditions. Mussels due to their limited dispersal as adults may also indicate local conditions, but due to their longer life span may reflect historic stressors to the particular area (Diamond and Serveiss 2001). By incorporating various taxonomic groups and averaging standardized taxonomic scores for them, we generated an overall rating for stream segments that represent multiple signals of stream conditions.

The primary reason for IDNR to combine and update BSC ratings and BSS designations is to support the implementation of Illinois' Wildlife Action Plan (State of Illinois 2005). Illinois Wildlife Action Plan is a science-based initiative for addressing the requirements of species in greatest conservation need so that rare or declining populations can be maintained or enhanced. The Wildlife Action Plan was developed to guide future conservation efforts by outlining specific areas where positive measurable impacts can be made with targeted efforts using limited dollars. Illinois' Wildlife Action Plan is comprised of seven campaigns, including a rivers and streams campaign. An updated rating process will provide a mechanism for targeting actions identified within the streams campaign and will help define the operational plans for Conservation Opportunity Areas (COAs). As actions are implemented, revised stream ratings based on new data will help managers determine if they are making progress implementing the aquatic goals of the Plan (i.e., quantifying progress). For example, this project provides a biological rating of the "integrity of water quality" throughout the state as referenced in action item #19 in the streams campaign. Additionally, the letter ratings and biologically significant streams designation will provide opportunities for protecting highly diverse and intact areas as indicated in Action #17 of the streams campaign (State of Illinois 2005).

Because of the considerable interest by a broad group of stakeholders in updating ratings and developing a process for future updates, the IDNR created a workgroup comprised of representatives from various divisions within IDNR (e.g., Fisheries, Watershed Protection), Illinois Natural History Survey, Illinois Nature Preserves Commission, and the Illinois Environmental Protection Agency. Additional workgroup members included representatives of Illinois Association of Wastewater Agencies, and environmental groups (The Nature Conservancy, Sierra Club, and Prairie Rivers). Workgroup members were important contributors to the process used in developing the ratings presented here; they helped identify available datasets, discussed limitations of data for integrity and diversity analyses, and reviewed draft rating processes and stream ratings. Their involvement was crucial for ensuring that our methods of combining and updating the two previous approaches for rating Illinois streams into a single enhanced process were robust and acceptable to the larger user group (see Appendix A for a list of workgroup members and their affiliations).

Job 1. Determine approach for designating stream ratings.

General Approach

There have been three previous publications that assigned ratings to Illinois streams; the Biological Stream Characterization (BSC) publications (Bertrand *et al.* 1996; Hite and Bertrand 1989) and Biologically Significant Illinois Streams (BSS; Page *et al.* 1992). The BSC publications used fish community data collected as part of the statewide basin survey program as their primary data source. Stream quality was assessed through the calculation of a fish index of biotic integrity score (IBI). The goal of the BSS project was to protect 100% of the stream-dependent biodiversity and additional datasets were used to identify biologically significant streams. These datasets included fish as well as mussel species richness and the presence of watch list, threatened and endangered aquatic species. The ratings that resulted from these projects relied heavily on the fish IBI. Streams rated as part of the BSC were assigned a letter rating of A-E, which were described as unique to restricted aquatic resources. A stream could only achieve the highest rating of an A if a fish IBI score could be calculated and it scored in the highest class (Bertrand *et al.* 1996; Hite and Bertrand 1989). Although macroinvertebrate data was considered for the BSC it was only used to assign a rating of D or E. Similarly, one of the criteria to achieve status as a BSS was a rating of A from the first BSC publication (Page *et al.* 1992).

This report describes an approach that combines, updates, and enhances the two previous methods for rating Illinois streams. Similar to the BSC publications one objective was to use datasets that consisted of community samples that were collected statewide. A second objective was to incorporate biological indices that have been developed for the state. Similar to the BSS publication we incorporated information from multiple datasets and identified streams that are significant based on various taxonomic groups rather than relying on the fish data as the primary stream integrity indicator. However, rather than using an additive approach similar to the original BSS which identified streams using fish IBI data, mussel species richness, or threatened and endangered species presence, the current process uses a holistic approach that combines datasets for a final rating.

Since the publication of the last BSC project (Bertrand *et al.* 1996) many additional initiatives have occurred that relate to stream biological resources. These include the development of indices for benthic macroinvertebrates and mussels (Tetra Tech, Inc. 2007; Szafoni 2002), and the revision of the fish IBI (Smogor 2000). The basin survey program has also continued and more recent fish and macroinvertebrate data are available.

One of the objectives for this project was to give equal weight to all communities of organisms found in streams if adequate and comparable sampling had occurred. This required interpreting raw data from different sources and attempting to classify it similarly. Another goal was to create a rating process that is data driven and quantifiable rather than relying on narrative information. The BSC publications included sport fishery and fish spawning/nursery area information that were narrative (Hite and Bertrand 1989; Bertrand *et al.* 1996). Since we used multiple datasets to derive a final rating, and this rating could be achieved through many combinations for any particular segment of stream, we developed a product that indicates which data contributed to the final rating.

This report describes two general approaches that result in assigning up to three designations to a stream segment. These are a diversity rating, integrity rating, and identification as a biologically significant stream. Although the approach to obtain the diversity and integrity ratings is similar we have not combined the two ratings for an overall rating. The reason that ratings have not been combined is that each one provides different types of information about the stream. The diversity rating is based primarily on species richness whereas the integrity rating is based on measures of intactness or wholeness. The diversity rating ultimately combines datasets that indicate species richness for each taxonomic group and prioritizes valley segments with high species richness. Diversity ratings were kept separate from the integrity rating since valley segments may also be important due to their intactness even though species richness expectations are not high. Intactness for fish and macroinvertebrates was determined from the indices of biotic integrity in comparison to least disturbed or reference sites. Intactness for mussels was determined in comparison to historical species richness expectations for a site. Three of the datasets that contribute to the integrity rating are multi-metric indices. The letter ratings of A-E were maintained for both the diversity and integrity ratings as these designations were used in the previous BSC revision.

The general approach for obtaining a diversity or integrity rating is a five step process.

1. Convert raw data to a metric or class score for a given site for each available dataset (i.e., fish, mussels, aquatic invertebrates).

2. Divide the metric score by the total number of classes to obtain a proportional score (P score) with a maximum of 1 for a site in order to standardize these datasets that may have different numbers of classes.
3. Calculate the average of the proportional scores within a given taxonomic group taken from different datasets in order to obtain a single taxonomic score (T score) where applicable (e.g., three potential datasets available for aquatic invertebrates).
4. Calculate the average proportional and/or taxonomic score for a valley segment based on multiple sites associated with the valley segment (e.g., average fish proportional score from multiple sites within a valley segment).
5. Determine the final diversity and/or integrity rating by calculating the average of the average proportional/taxonomic scores (e.g., average of the average fish, mussel, and aquatic invertebrate proportional scores).

The diversity rating also integrates data that provide information about taxa that were deemed important due to their rarity (e.g., threatened and endangered species). These datasets have only two classes, which in some instances could lower the final score if averaged with the other available information. Since the presence of these taxa indicates a higher diversity condition, we include them as bonus points to the diversity score. Therefore, the diversity rating has a potential score of greater than 1 while the integrity rating has a maximum score of 1 since no bonus points are involved (See Job 5 for a detailed description and examples of the final rating process).

We defined Biologically Significant Streams (BSS) generally as those streams that have a high rating based on datasets from at least two taxonomic groups. This can be achieved by obtaining an A rating either for diversity or for integrity that is based on data from two or more taxonomic groups. A second way to achieve this status is for a stream segment to have metric scores in the highest class for at least two taxonomic groups when considering the combined data from the diversity and integrity ratings. While these criteria may seem more rigorous than the previous BSS assessment we believe this is merited. By requiring BSS segments to have either an A rating or high metric scores from separate assessments we are assuring that only the highest rated reaches are given this biologically significant status. By considering two taxonomic groups, we are confident in the BSS designation as two signals are indicating high biological significance within the stream.

Job 2. Investigate availability and adequacy of statewide data for use in this process.

For all datasets used in this project we only considered data collected in the past decade (1997-2006) for contribution to the final analysis. Data that are collected as part of IDNR, IEPA, or INHS monitoring programs were used. This was done primarily to ensure that collection methods are standardized, repeatable, and will be continued in the future so that data will be available for revisions of these ratings. The first meeting with the project stakeholders occurred in December 2006 at which time the proposed datasets for inclusion in this process were presented. One of the goals of the meeting was to obtain feedback from the group as to the appropriateness of the datasets and other possible sources of data.

There are a few standards that were applied to all datasets. For datasets that did not already have classes associated with them we used percentiles to determine our class breaks. Classes were independently developed for these datasets using each sample collection as an independent record rather than pooling samples from a single site. For example, species richness expectations were based on the number of species you would expect to find in a single sampling event.

For datasets that already had classes associated with them we maintained the classes that had already been established. Both the fish IBI and the macroinvertebrate IBI (MIBI) have classes that are based on data from reference or least-disturbed sites. The top class for these two datasets is the 75th percentile of reference sites and above. In order to maintain similarity across data sets we used the 90th or 95th percentile as the boundary for the highest class for datasets that were not developed with a reference site approach. Our rationale was that by raising the standard for the top class for these datasets to the 90th percentile then the highest class would be similarly restrictive as the datasets that did have reference site data available.

All metric/class scores range from "1" to a greater number with the greatest number always representing the highest class. For example the raw metrics for fish species richness from the IBI has 6 classes with class 6 being the highest. We first considered data that was collected within the past decade. However, if a site had more than one sample from the past decade we used the sample that had the highest class score for inclusion in the final rating calculation. We used this approach rather than taking the most recent sample or an average of the samples as the highest class score represents a conservative estimate of the biological potential for the site. It also accounts for variation that may occur with sampling. We did not want to use an average of the class scores since the average could represent a condition that had not been found at the site.

Fish

We compiled fish data collected in association with the IDNR cooperative basin surveys and other department monitoring for this project. Basin surveys began in the 1980's with watersheds currently sampled throughout Illinois on a five year rotation (IEPA 2002). These data were then forwarded to the regional IDNR stream biologists for verification that the samples included were representative of community samples with adequate sampling efficiency. Some additional data were also received from the regional biologists that were not yet available in the statewide database.

We limited our samples to primarily wadeable streams for which the Illinois Index of Biotic of Integrity (IBI) was created (Smogor 2000). Although it is possible to calculate an IBI score for larger river sites through extrapolation of the regional IBI models, we wanted to verify that in such instances we still had confidence in the IBI. The regional IBI score graphs were consulted for all sites that had an extrapolated IBI score and best professional judgment was used to determine if the width of the stream exceeded the range of application for the IBI.

One of the ten metrics comprising the fish IBI score is the number of native fish species (Smogor 2000). We retrieved this single metric from the fish data summaries that we compiled and used it as a component of the diversity rating. This metric is assigned a class rating of 0-6 for the fish IBI according to IBI region. The only modification that we made to these classes was to add "1" to each class thereby eliminating the "0" class. Resulting fish class scores ranged from 1-7. We eliminated the 0 class since this class did not represent a true zero in terms of an absence of fish. A total of 731 sites were used in the diversity score analysis (Table 1). There were fewer sites with fish species richness than fish IBI scores since the individual metrics scores used to calculate the fish IBI were not always available.

Fish IBI scores were used to calculate the integrity rating. Ten metrics are used to determine the fish IBI (Smogor 2000). Each of these metrics is scored from 0-6; the metrics are then summed to yield an overall fish IBI score from 0 – 60. The fish IBI scores are then put into five classes. We used existing integrity classes (Smogor 2005), however we reversed the numbering of the classes to give the sites with the highest IBI scores a 5 instead of a 1. A total of 744 sites with calculated Fish IBI scores were used in the final integrity score analysis (Table 2).

Mussels

Data from the INHS mollusk collections database and IDNR biologists were obtained (http://www.inhs.uiuc.edu/cbd/collections/mollusk/molluskintro.html). Records associated with freshwater snails, fingernail clams, zebra mussels, and Asian clams were omitted. Records associated with habitat that was not a stream or a river were also omitted. These locations were determined by identifying point locations in ArcMap that were greater than 60m from the nearest digitized stream. Samples were omitted if they had textual descriptions of the following: lakes, ponds, sloughs, reservoirs, marshes, borrow pits, gravel pits, wetlands, coal strips, quarries, inland seas, lagoons, ditches. In order to query data that were representative of community samples, we restricted our data based on a list of collectors' names obtained from Kevin Cummings, the INHS malacologist and mussel database manager (Appendix A).

A mussel species richness of ten species or greater was previously used to identify BSS (Page *et al.* 1992) and is also used as the threshold for defining the highest classification for the species richness factor in the Illinois Mussel Classification Index (Szafoni 2002). The INHS mollusk data was used to determine if mussel species richness expectations are similar across different sized streams (based on link code) within different drainages. This analysis was undertaken in order to determine if a mussel species richness of 10 species is an appropriate number to apply to all Illinois streams.

Species richness data from 946 sites that had community samples of live mussels post 1980 were projected in ArcMap. Link number was defined as the number of first order streams based on the 1:100,000 National Hydrography Dataset (NHD) upstream of a given stream reach (Shreve 1967, USGS 2004). The link numbers were joined to the mussel data based on spatial location and link codes were assigned to each site (Table 3).

Digitized stream lines were coded according to major drainage, (Illinois, Mississippi, Ohio, and Wabash) and type (mainstem or tributary streams). Species richness data for the 946 sites with community samples of live mussels post 1980 were spatially joined to the stream drainage and type data. These data were examined at the 50th, 75th, 80th, 90th and 95th percentiles based on the link code groups 1, 2-3, 4-6, (corresponding to small, medium, and large streams) for the tributaries within each drainage area. Three classes were developed for mussel species richness expectations for each of the major drainages based on the percentiles within the link code groupings of the tributary streams (Table 4). Class one consisted of samples that were below average richness within the drainage (0-49th percentile), class two were above average samples (50-89th), and class three were exceptionally high scoring samples (90th percentile and above (Table 4)). The classes were developed based on the 1980+ data but only data from 1997+ were included in the final rating analysis. Data from both the INHS mollusk collection and IDNR sampling were used for the final ratings. A total of 596 sites were used for the final diversity score analysis (Table 1).

Two mussel intactness measures that contributed to the integrity rating were calculated, historical intactness and single sample intactness. Historical intactness was calculated for sites that had two or more samples while single sample intactness was used at sites that had only been sampled once. Intactness was calculated for a site using the sample from the past decade with the highest species richness of live mussel species divided by the total number of species including dead and relict specimens. For single sample intactness the total number of species was from the single sample while for historical intactness it included all the species found at the site from multiple samples. Intactness was only calculated for sites that had a community sample. Intactness classes consisted of the 1-10th percentile for class 1 and the 11-50th, 51-89th and 90th+ percentile for classes 2, 3, and 4 respectively. We developed classes for historic and single sample intactness independently. Similar to mussel species richness expectations, classes were assigned according to drainage and stream size (Tables 5 and 6). If both historical and single sample intactness were available for a site, then historical intactness was used in the final diversity ratings. A total of 366 historical intactness sites and 329 non-overlapping single sample intactness sites were used for the final integrity score analysis (Table 2).

<u>Freshwater Mussel Classification Index (MCI)</u>

Data were obtained from Bob Szafoni (IDNR) for sites where the MCI has been calculated (Szafoni 2002). Although the MCI is comprised of multiple metrics like the fish IBI and MIBI, this index has not been developed with a comparison to reference sites. A complete statewide coverage of sites for which the MCI has been calculated was not available for our analysis. However, this dataset is introduced in this project with the expectation that coverage will be expanded in the future.

The MCI was used to contribute to the integrity rating. Four metrics are used to determine the MCI, species richness, abundance, presence of intolerant species, and recruitment (Szafoni 2002). Each of these metrics is scored and the scores are then summed to determine an index score. Szafoni (2002) defines five classes for the index ranging from 0-4. Sites with a class score of 0 had no live mussels present and were not included in the final rating calculation. A total of 134 sites were used for the final integrity score analysis (Table 2).

Aquatic invertebrates

Critical Trends Assessment Program (CTAP; http://ctap.inhs.uiuc.edu/index.asp)

Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies; EPT) data have been collected since 1997 as part of the CTAP conducted by the INHS. Sites were originally selected using a random design and are typically on smaller streams than those included in the IDNR basin surveys (pers. comm. Ed DeWalt). CTAP sampling is conducted on a five year rotation and those sites sampled during 1997-2001 were revisited in 2002-2006. Species belonging to EPT orders of aquatic insects can be used as indicators of stream condition (DeWalt *et al.* 1999). These data were obtained from Dr. R. Edward DeWalt of the INHS, the CTAP professional scientist in charge of stream monitoring.

Three classes were assigned to the CTAP EPT data and were used to contribute to the diversity rating. Class one was represented by the 0-49th percentile, class two 50-89th, and class three by the 90th percentile and above (Table 7). These classes had similar breaks to those developed by CTAP. A total of 179 sites were used for the final diversity score analysis (Table 1).

Benthic Macroinvertebrate Stream Condition Index

The IEPA recently reevaluated and changed its methodology for collecting aquatic invertebrates and developed a Stream Condition Index (Tetra Tech, Inc. 2007) referred to as the Macroinvertebrate Index of Biotic Integrity (MIBI) in this project. Data using the revised collection methodology has been gathered at basin survey sites since 2001. These data were obtained from the IEPA office in Springfield.

One of the seven metrics comprising the MIBI is total taxa richness. This metric was used to contribute to the diversity rating. This individual metric did not have classes already developed for it. To do so we used the same approach that was used to define classes for fish species richness from the fish IBI (Smogor 2000). Taxa richness values ranged from 0 to 35+ and were placed into seven classes (Table 8). A total of 452 sites rated with these classes were used for the final diversity score analysis (Table 1).

The total MIBI score, based on seven metrics (Tetra Tech, Inc. 2007), was used to contribute to the integrity rating. Each metric is standardized to a potential maximum score of 100. The seven metric scores are then averaged for the overall MIBI score. This score is then placed into one of four classes. We maintained these four classes for this project. A total of 452 sites with total MIBI scores were used for the final integrity score analysis (Table 2).

Bonus Point Data

The following three datasets were added as bonus point data instead of being averaged into the diversity score. Initially the threatened and endangered species richness was awarded a class value of either 1 or 2 and then averaged into the diversity score. However, using this approach there were instances where a class value of 1 with a proportional score of 0.5 was actually lowering the final diversity score. Therefore, it was decided to use the threatened and endangered species richness, as well as two other datasets, as bonus points so that the presence of these taxa always improves the diversity rating. To determine how many bonus points each dataset should contribute to the final score we first considered the weight of the dataset as if an average were being calculated. For instance, if data are being added at a point where three datasets can be averaged then the bonus points should contribute a maximum of 1/3 of the final score. A description of each data set considered as bonus points and their respective scores follows.

S1S2 Ephemeroptera, Plecoptera, and Tricoptera

Currently there are no EPT species listed as endangered or threatened by the Illinois Endangered Species Protection Act (http://dnr.state.il.us/espb/datelist.htm). However, some species within these orders have been identified as critically imperiled (S1) or imperiled (S2) at the state level by an INHS entomologist (DeWalt *et al.* 2005, Favret and DeWalt 2002). These conservation status ranks are used by NatureServe (http://www.natureserve.org/). Data pertaining to the presence of these species within Illinois were obtained from the INHS EPT collections databases (http://www.inhs.uiuc.edu/cbd/EPT/index.html).

S1S2 EPT data are added to the macroinvertebrate taxonomic score as bonus point data. The maximum number of bonus points is awarded to samples with three or more species as this corresponds to the 90^{th} percentile for the number of species found per sample. Samples with 1-2 species are awarded half the maximum. The macroinvertebrate taxonomic score has three potential datasets. The diversity score prior to adding other bonus point datasets is based on the average of the macroinvertebrate taxonomic score, the fish proportional score and the mussel proportional score. Therefore, the S1S2 EPT data potentially contribute $1/9^{th}$ (0.11) of the pre-bonus points diversity score. We therefore, assigned 0.11 for samples with 3+ and 0.055 for 1-2 species.

There were some valley segments that had S1S2 EPT data available but did not have other macroinvertebrate data. In these cases we added the bonus points after the fish and mussel taxonomic scores had been averaged. However, since the data was added at a different point in the process we divided the bonus points by three since they should contribute to a third of the diversity score prior to the T&E and Crayfish bonus points being added. Therefore, for valley segments without other macroinvertebrate data 0.037 was added when there were 3+ species and 0.018 for samples with 1-2 species. A total of 104 sites were used for the final diversity score analysis (Table 1).

Other

Data were obtained on the presence of amphibians and reptiles in Illinois from the INHS amphibian and reptile collection (http://www.inhs.uiuc.edu/cbd/collections/amprep/amprepintro.html). However, due to a lack of statewide coverage and systematic community sampling these data were not included in the final project.

The possibility of including additional plant species was pursued. The INHS has a herbarium collection (http://www.inhs.uiuc.edu/cbd/collections/plants.html). State experts were consulted in order to determine if other potential datasets were available. However, no additional species were included since there have not been systematic statewide surveys of plants associated with stream habitat.

Job 3. Overlay data on stream network in a geographic information system (GIS).

All data sets were overlaid on the 1:100,000 – scale, National Hydrography Dataset (NHD; USGS 2000) that was refined for a previous project (Holtrop and Dolan 2003). Point locations of data that were greater than 60m from the nearest digitized stream line were visually inspected using an overlay of aerial images to determine if the point was associated with a large river or a small stream that was not digitized. Points that were associated with large rivers were kept in the data file for analysis while those associated with an undigitized stream were separated into a different file and omitted from further analysis. Points that did not fall into either of these categories were further investigated to determine if there was an error with the spatial coordinates. Errors were remedied where possible and points that could not be corrected and still fell greater than 60m from the nearest stream were omitted.

Point data or sampling sites for the final ratings were summarized according to valley segment. Valley segments are aggregations of linearly adjacent physically similar stream reaches (Seelbach *et al.* 1997). Physical characteristics used to define valley segments were related to stream size (drainage area), surficial geology (bedrock, coarse substrates), discharge (flow yield), and gradient. Valley segments were independently derived prior to assigning ratings using a spatially-constrained clustering method based on the cluster affinity search technique. Valley segment numbers were assigned to sampling sites through a spatial join in ArcMap 9.2. Datasets were then associated with each other for calculation of the final rating according to valley segment number in a Microsoft Office Access 2003 Query.

Job 4. Identify stream ratings.

The initial process for assigning stream ratings was presented to stakeholders at a meeting in June 2007. This process was further refined prior to the distribution of the first version of the preliminary ratings in August 2007. Based on feedback from the stakeholders the process was altered slightly before the distribution of a second version of the final ratings in October 2007.

Final Diversity Score and Rating

As outlined under Job 1, the general approach for determining final diversity scores is a five step process. Class/metric scores are converted to proportional scores by dividing by the total number of classes. When there are multiple datasets available for a particular taxonomic group then the average of these proportional scores is used to determine the taxonomic score (e.g., macroinvertebrate taxonomic score). We used this approach instead of keeping the datasets separate and averaging them all into a final score in order to give equal weight to the different taxonomic groups. We averaged the proportional scores within a taxonomic group since they were derived from separate assessments and their average represents the combined signal from all the data sources. When multiple sites are associated with a particular valley segment for a dataset, the average of these proportional scores is used to calculate the final diversity score. An average from the different sites is used rather than considering the highest proportional score from the valley segment since conditions within the stream segment may vary and an average for the whole valley segment is a better representation than the signal from a single site. Therefore, once proportional and taxonomic scores have been calculated for each data set the final diversity score is calculated as indicated below.

Diversity Score = $\bar{X}$ ($\bar{X}$ fish species richness P scores + $\bar{X}$ mussel species P scores + $\bar{X}$ macroinvertebrate T Scores) + threatened and endangered species bonus points + crayfish bonus points, where P score = proportional score and T score = taxonomic score

To further illustrate this process we present several examples (Table 9). In the first example, there is only one dataset associated with the valley segment. The fish species richness is 15 which for the particular region that the valley segment falls within corresponds to a class/metric score of 5. To obtain the proportional score 5 is divided by the total number of classes which is 7. Since there are no other datasets to average with the fish species richness the final diversity score is the same as the fish proportional score. A final diversity score of 0.714 equates to a letter rating of C.

In the second example there are data available from three taxonomic groups. The fish species richness is 22 which equates to a class score of 6 and a proportional score of 0.857. The mussel species richness is 6 which equates to a class score of 2 and a proportional score of 0.667. The macroinvertebrate taxa richness is 42 which equates to a class score of 7 and a proportional score of 1. The diversity score is determined by averaging the three proportional scores. The final score of 0.841 corresponds to a letter rating of C.

The third example has two sets of macroinvertebrate data as well as fish and mussel data. Before the diversity score can be calculated a macroinvertebrate taxonomic score is determined. The fish species richness is 10, translating to a class/metric score of 3 and a proportional score of 0.429. The mussel species richness is 1, translating to a class/metric score of 1 and a proportional score of 0.333. The macroinvertebrate taxa richness is 31 equating to a class/metric score of 6 and a proportional score of 0.857. The CTAP EPT species richness is 17 equating to a class/metric score of 2 and a proportional score of 0.667. The macroinvertebrate taxonomic score is determined by averaging the macroinvertebrate taxa richness proportional score and the CTAP EPT proportional score. The final diversity score (0.51 with a diversity rating of D) is calculated by averaging the fish and mussel proportional scores and the macroinvertebrate taxonomic score.

The fourth example also has two datasets available for macroinvertebrates. However, one of the datasets is S1S2 EPT bonus data. The CTAP ETP species richness is 20 representing a class/metric score of 3 and a proportional score of 1. There is one S1S2 EPT species associated with the valley segment awarding 0.055 bonus points. The macroinvertebrate taxonomic score is therefore the CTAP EPT proportional score plus the S1S2 EPT bonus points. Since there is no other data available the final score is equal to the macroinvertebrate taxonomic score (1.055 with a diversity rating of A).

The final example illustrates the procedure for dealing with valley segments that may have more than one sampling site associated with them and how to calculate the final diversity score using threatened and endangered species bonus points. The fish species richness is 33 equaling a class/metric score of 7 and a proportional score of 1. There are two mussel sites associated with the valley segment with species richness of 1 and 13. These correspond to class/metric scores of 1 and 3. To determine the final proportional score for the mussels the average is taken of the two site proportional scores. The pre-bonus point diversity score is then the average of the fish and mussel proportional scores. There are two threatened and endangered species associated with the valley segment equating to 0.2 bonus points. Once these are added to the pre-bonus point diversity score of 0.889 the final diversity score is 1.089 with an A rating.

The cut-offs for the final diversity letter ratings were determined by visually inspecting the distribution of the diversity scores (Figure 1). We also attempted to have a similar percentage of valley segments within each letter category as the previous BSC projects. A total of 1127 valley segments were assigned a diversity rating of A-E (Figure 2). This represents 3% of the total 38046 valley segments that exist for the state of Illinois. Of the valley segments that were rated, the percentage with the assignment of the ratings A-E is 13, 22, 38, 25 and 1 respectively. While this procedure has been developed for assigning ratings using multiple data sets approximately one half of the total valley segments that were rated used data from only one dataset (Table 10).

Final Integrity Score and Rating

As outlined under Job 1, the general approach for determining final integrity scores is a five step process. Once proportional and taxonomic scores have been calculated for each data set the final integrity score is calculated as indicated below.

Integrity Score = $\bar{X}$ ($\bar{X}$ fish IBI P scores + $\bar{X}$ MIBI P scores + $\bar{X}$ mussel T scores), where P score = proportional score and T score = taxonomic score

We provide several examples to further illustrate this process (Table 11). In the first example only the single dataset of macroinvertebrate IBI is associated with the valley segment. The MIBI score is 39.99 which equals class 2 out of 4; therefore the proportional score is 0.5. Since there are no other datasets available for this valley segment the final integrity rating is also 0.5 (Integrity Rating C).

In the second example both the MIBI and fish IBI are available. The fish IBI score is 47 corresponding to class 4 and a proportional score of 0.8. The MIBI score is 65.39 corresponding to class 3 and a proportional score of 0.75. The average of the fish IBI and MIBI proportional scores is calculated to determine the final integrity score of 0.775 which equates to a B rating.

In the third example, the fish IBI, MIBI, and two mussel datasets are available. The fish IBI score is 55 which is a class 4 score with a proportional score of 0.8. The MIBI score is 78.23 with a class score of 4 and a proportional score of 1. The mussel classification index score is 16 with a class score of 4 and a proportional score of 1. The single sample intactness percentage is 29 which is a class 2 score and a proportional score of 0.5. The two mussel proportional scores are averaged for a mussel taxonomic score of 0.75. The final integrity score is then the average of the fish IBI proportional score, the MIBI proportional score, and the mussel taxonomic score. The final score equals 0.85 and is equivalent to a B rating.

The cut-offs for the final integrity letter ratings were determined by visually inspecting the distribution of the integrity scores (Figure 3). We also attempted to have a percentage of rated valley segments within each letter category similar to the previous BSC projects. A total of 1019 valley segments were assigned an integrity rating of A-E (Figure 4). This represents 2.7% of the total valley segments. The percentage with the assignment of ratings A-E is 9, 31, 45, 10 and 5 respectively. While this procedure has been developed for assigning ratings using multiple data sets approximately one half of the total valley segments that were assigned integrity scores used data from only one dataset (Table 12).

The first BSC publication (Hite and Bertrand 1989) rated 478 streams with data from 920 samples (Table 13). Fish IBI values were used to rate 850 sites, narrative fisheries information was used at 67 sites, and 3 stream segments were rated using macroinvertebrate data. The second BSC publication (Bertrand *et al.* 1996) rated 746 streams. The percentage of streams with A-E from the first publication was 4, 30, 48, 17 and 1 respectively. The percentages from the second publication were 4.5, 33.5, 50, 11.5 and 0.5 respectively. The minimum stream segment length that a site rating was applied to for BSC was 5 miles (Bertrand *et al.* 1996). There are 1158 valley segments that have an assigned letter rating in the current project. Due to the aggregation of data based on the spatial unit of valley segments, the extent of our ratings is visually very different than the previous BSC publications.

Biologically Significant Streams

There were a total of 1366 valley segments with data associated with them. Nine percent (122) of all segments with associated data were identified as being biologically significant. The previous project (Page *et al.* 1992) identified 132 streams as biologically significant. Our primary criteria requiring a valley segment to contain the highest class score from two different taxonomic groups accounted for 84% of all BSS identifications. However, most valley segments (56%) that were identified as biologically significant also received an A rating for Diversity and/or Integrity (Table 14).

Job 5. Document rating process and generate map of stream ratings.

Process for Updating Ratings

We suggest that the stream ratings be updated and published after the completion of each round of basin surveys. Therefore, there should be a revision of ratings approximately every 5-6 years. With each update a new set of data from each of the sources will have to be selected based on the recent data criteria (within the last ten years). For certain datasets such as the fish IBI and macroinvertebrate IBI the values that correspond to the classes/metric scores will not have to be recalculated since they were already established. However, for other datasets such as the mussel species richness and intactness data, the number of species that correspond to the percentiles that were used to determine class scores will undoubtedly change with the collection of additional data. For these datasets, the values that represent the different class scores should be recalculated using the new data for each revision until these values can be more formally established.

Fish Data

The fish data used in this project were obtained from the IDNR basin surveys and other monitoring programs and used classes that had been established for the fish IBI. If any additional revisions to the fish IBI occur between updates then the number of species corresponding to classes 1-7 may need to be changed. Any updates to these data would require new data to be retrieved from the IDNR fisheries database.

Mussel Data

The freshwater mussel data within the INHS mollusk collections database is currently being attributed with a field that indicates if a sample was randomly taken, purposefully surveyed, or unknown. Once this has been completed and additional data on freshwater mussel communities has been collected, both the mussel species richness expectations and intactness should be recalculated. New percentiles should be determined in order to establish revised classes for each update until these relationships stabilize. This would be particularly relevant for streams in the Mississippi, Ohio, and Wabash drainages where certain sized streams were not assigned classes due to the number of samples being too low to base percentiles on (Tables 5 and 6).

A new mussel database funded by a State Wildlife Grant (SWG) has also been developed. Paired with the possibility of a statewide sampling effort also funded by SWG there should be additional data in the future to contribute to more Mussel Classification Index calculations and determination of historical intactness.

Aquatic Invertebrate Data

Critical Trends Assessment Program

The number of species that correspond to the percentiles that were used to establish classes 1-3 for the CTAP data should be recalculated for any updated version of this project until these values can be more formally established. With additional sampling the species expectations may change for the three classes.

Benthic Macroinvertebrate Stream Condition Index

If any additional revisions to the MIBI occur then the number of taxa corresponding to classes 1-7 may need to be changed. Otherwise, a project update would only require gathering more recent data from IEPA.

S1S2 Ephemeroptera, Plecoptera, and Tricoptera

The number of species that correspond to the percentiles that were used to establish the two bonus point totals should be recalculated for an updated version of this project. Also, with an updated project the number of datasets contributing to a diversity score may be different. The number of datasets should be taken into account when determining how many bonus points to assign. Additionally, in the future these S1S2 species may be protected under the Illinois Endangered Species Protection Act and would therefore be considered under the category of threatened and endangered species.

Crayfish Data

Crayfish data may be incorporated differently into a revised diversity rating in the future if a systematic state-wide sampling program is developed. The number of species that correspond with the 95th percentile should be recalculated when additional data are collected in the future.

Threatened and Endangered Species Data

The number of species that correspond to the percentiles that were used to establish the two bonus point totals should be recalculated for an updated version of this project. Also, given that with an updated project the number of datasets contributing to diversity score may be different this should be taken into account when determining how many bonus points to assign. The Illinois Endangered Species Protection Board meets every 5 years to determine the most current list of threatened and endangered species. The current list was revised in 2004. It will be revised again in 2009. Therefore, the next revision of the streams ratings should consider the updated list of species.

Final Scores and Letter Ratings

The cut-offs for the letter ratings are based on the distribution of the final scores. In a future project these cut-offs could change as new data are analyzed. Therefore, the final scores that correspond to the letter ratings A-E should be reevaluated with any update.

Conclusions/Discussion

One of the goals of the BSC was to update stream ratings on an annual basis and to publish the revised ratings every five years. However, the original BSC stream ratings were only updated once based on data that was collected up until 1993. Similarly, the BSS project was based on data collected through 1991 and has not been updated since. Therefore, the stream designations identified in these projects are based on data that is at least 14 years old. Given that these ratings are used by a diverse group of stakeholders, it is clear an updated version is required.

Since the publication of BSC and BSS there have been new initiatives to collect biological information relevant to streams such as the Critical Trends Assessment Program, Mussel Classification Index, and the Benthic Macroinvertebrate Stream Condition Index. The fish IBI has also been revised (Table 15) and the list of threatened and endangered species has changed since the one used to identify BSS. With the additions and changes to these data sources it was pertinent to reassess the strengths and weaknesses of the previous stream ratings projects and incorporate the best features of both projects that are relevant to the data that is currently available. This has resulted in a single product that has combined aspects of both BSC and BSS.

In keeping with the Illinois Comprehensive Wildlife Conservation Plan's stream habitat goal that:

"High–quality examples of all river and stream communities . . . are restored and managed within all natural divisions in which they occur"

the current stream ratings and identification of biologically significant streams provide a new and updated tool in which to identify and target such areas. By the combination of multiple datasets from different taxonomic groups this project gives ratings that are a holistic representation of stream biological resources. Through the consideration of data sources derived from organisms other than fish, ratings were applied to 483 valley segments that did not have fish data associated with them. The CWCP has identified crustacean, fish, insect, and mollusk species in greatest need of conservation therefore it is appropriate that these taxonomic groups are all given consideration in this project.

There are a number of reasons why previous stream ratings may have changed. These include the new process for rating streams, the inclusion of new datasets, the revision to the fish IBI, and the reflection of changes in stream condition. These new ratings can assist in identifying streams that are in need of restoration or improved conservation. Given that less than 5% of the valley segments in the state have data associated with them, this project also indicates data gaps and can help prioritize survey efforts in the future. Currently the fish IBI is only applicable to wadeable streams. It would be useful to have a tool to identify the specific stream reaches in Illinois where the current fish IBI is applicable as well as develop headwater and large river fish IBIs. There is also a need for a systematic statewide survey of mussels in order to develop better species expectations and classes for this dataset.

The previous BSC projects used site data to rate stream segments that were a minimum of 5 miles in length. Due to the current approach of using valley segments as the spatial unit for aggregating data, the extent of the new ratings is different. For management purposes, IDNR may wish to extend biologically significant stream reaches upstream.

The final product of diversity and integrity ratings with the identification of biologically significant streams indicates the data sources that contribute to each final rating and includes the proportional scores for these data. This will enable different stakeholders with varying goals to use the ratings and contributing data for their particular purposes. For example, if a stakeholder wanted to target their efforts at streams with high mussel species diversity they would be able to identify those streams according to the mussel species richness proportional score contributing to the final diversity score. Similarly, efforts focused at streams with a high fish IBI score could consider the fish IBI proportional score contributing to a final integrity score.

Both fish and macroinvertebrate data that are collected as part of the statewide basin surveys were used for this project. Mussel data is also anticipated to be collected as part of this program in the future. The major data collection programs (collaborative basin surveys, CTAP, Endangered Species Board updates) used in this project operate on a five year interval to assess streams statewide. Therefore, it would be appropriate that the stream ratings and identification of biologically significant streams be updated and published every 5-6 years after the completion of a round of basin surveys.

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Tables

Table 1. The number of sites from each dataset used to calculate diversity scores.

Diversity Dataset	Number of Sites
Fish Species Richness	731
Macroinvertebrate Taxa Richness	452
CTAP EPT Species Richness	179
S1S2 EPT Species Richness	104
Mussel Species Richness	596
Crayfish Species Richness	18
Threatened and Endangered Species Richness	413
Total	2493

Table 2. The number of sites from each dataset used to calculate integrity scores.

Integrity Dataset	Number of Sites
Fish IBI	744
Macroinvertebrate IBI	452
Mussel Classification Index	134
Mussel Single Sample Intactness	329
Mussel Historical Intactness	366
Total	2025

Table 3. The relationship between link code, link number, and stream order.

		Notes
1		all 1st and 2nd order segments, a few very small drainage area 3-4 order segments.
2	21 - 150	remaining 3rd order segments, majority of 4th order segments, and a few very small 5th order segments.
3	151 - 180	remaining large 4th order segments, medium sized 5th order segments.
4	181 - 725	remaining large 5th order segments, medium sized 6th order segments.
5	726 - 1300	remaining large 6th order stream segments.
6	1301 - 6500	all 7th order segments.
7	6501 - 10271	all 8th order segments.

Table 4. Mussel species richness ratings based on expectations according to drainage and stream size.

Stream Size	Drainage	Class 3 (90th percentile+)	Class 2 (50th - 90th percentile)	Class 1 (<50th percentile)
Small (Link code 1)	Illinois	8+	3-7	<3
	Mississippi	6+	2-5	<2
	Ohio	3+	2	1
	Wabash	9+	3-8	<3
Medium (Link codes 2-3)	Illinois	12+	5-11	<5
	Mississippi	11+	5-10	<5
	Ohio	4+	2-3	<2
	Wabash	11+	5-10	<5
Large (Link Codes 4-6)	Illinois	12+	5-11	<5
	Mississippi	12+	7-11	<7
	Ohio	6+	2-5	<2
	Wabash	14+	6-13	<6
Mainstem (Link Code 7)	Illinois	11+	9-10	<9
	Mississippi	21+	15-20	<15
	Ohio	14+	6-13	<6
	Wabash	10+	3-9	<3

Table 5. The mussel single sample intactness percentages that correspond to classes 1-4 for each drainage and stream size (according to link code).

	Single Sample Intactness Percentage			
	Class 1	**Class 2**	**Class 3**	**Class 4**
Illinois				
Link Code 1	1-27	28-65	66-83	84+
Link Code 2-3	1-26	27-71	72-90	91+
Link Code 4-6	1-21	22-50	51-83	84+
Mississippi				
Link Code 1	1-19	20-50	51-83	84+
Link Code 2-3	1-35	36-71	72-88	89+
Link Code 4-6	1-32	33-64	65-77	78+
Ohio				
Link Code 1	1-20	21-42	43-54	55+
Link Code 2-3	1-12	13-44	45-76	77+
Link Code 4-6	na	na	na	na
Wabash				
Link Code 1	1-33	34-60	61-79	80+
Link Code 2-3	1-20	21-50	51-82	83+
Link Code 4-6	1-24	25-55	56-88	89+

Table 6. The mussel historical intactness percentages that correspond to classes 1-4 for each drainage and stream size (according to link code).

	Historical Intactness Percentage			
	Class 1	Class 2	Class 3	Class 4
Illinois				
Link Code 1	1-22	23-50	51-79	80+
Link Code 2-3	1-20	21-62	63-79	80+
Link Code 4-6	1-11	12-44	45-69	70+
Mississippi				
Link Code 1	na	na	na	na
Link Code 2-3	1-20	21-57	58-79	80+
Link Code 4-6	1-16	17-45	46-63	64+
Ohio				
Link Code 1	1-15	16-27	28-59	60+
Link Code 2-3	1-14	15-31	32-53	54+
Link Code 4-6	na	na	na	na
Wabash				
Link Code 1	1-17	18-50	51-71	72+
Link Code 2-3	1-14	15-41	42-71	72+
Link Code 4-6	1-13	14-40	41-62	63+

Table 7. Number of species corresponding to the three classes developed for the Critical Trend Assessment Program's Ephemeroptera, Plecoptera, and Tricoptera data. The species from the three orders are considered together.

Class 3 (90th+ percentile)	19+ Species
Class 2 (50-89th percentile)	9-18 Species
Class 1(<50th percentile)	1-8 Species

Table 8. Number of taxa corresponding to the 7 classes developed for the MIBI.

Metric Score	Richness
7	35
6	31-34
5	25-30
4	19-24
3	13-18
2	7-12
1	0-6

Table 9. Examples of calculating diversity scores.

	Example with single dataset	Example with three taxonomic groups	Example with two macroinvertebrate datasets	Example with S1S2 EPT bonus points	Example with two mussel sites and threatened and endangered species bonus points
Valley Segment	21679	39073	37913	3557	44269
Fish species richness	15	22	10		33
Fish species richness class/metric score	5	6	3		7
Fish proportional score	0.714 (5/7)	0.857 (6/7)	0.429 (3/7)		1 (7/7)
Mussel species richness		6	1		1 and 13
Mussel species richness class/metric score		2	1		1 and 3
Mussel proportional score		0.667 (2/3)	0.333 (1/3)		0.667 (average of 0.33 and 1)
Macroinvertebrate taxa richness		42	31		40
Macroinvertebrate taxa richness class/metric score		7	6		7
Macroinvertebrate taxa richness proportional score		1 (7/7)	0.857 (6/7)		1 (7/7)
CTAPEPT species richness			17	20	
CTAP EPT species richness class/metric score			2	3	
CTAP species richness proportional score			0.667 (2/3)	1 (3/3)	
S1S2 EPT species richness				1	
S1S2 EPT species richness bonus points				0.055	
Macroinvertebrate taxonomic score		1	0.76	1.055	1
Diversity Score 1	0.714	0.841	0.51	1.055	0.889
Crayfish species richness					
Crayfish species bonus points					
Threatened and Endangered species richness					2
Threatened and Endangered species bonus points					0.2
Diversity Score 2	0.714	0.841	0.51	1.055	1.089
Diversity Rating	C	B	D	A	A

Table 10. The number of datasets that contributed to final diversity ratings.

Datasets	Total Valley Segments
1	565
2	370
3	134
4	44
5	11
6	3
Total	1127

Table 11. Examples of calculating integrity scores.

	Example with single datset	**Example based on Fish and Macro IBIs**	**Example with average of mussel datasets**
Valley Segment	38663	29766	44269
Fish IBI score		47	55
Fish IBI class/metric score		4	4
Fish IBI proportional score		0.8 (4/5)	0.8 (4/5)
Macroinvertebrate IBI score	39.99	68.39	78.23
Macroinvertebrate IBI class/metric score	2	3	4
Macroinvertebrate IBI proportional score	0.5 (2/4)	0.75 (3/4)	1 (4/4)
Mussel Classification Index score			16
Mussel Classification Index class/metric score			4
Mussel Classification Index proportional score			1 (4/4)
Mussel single sample intactness percentage			29
Mussel single sample intactness class/metric score			2 (2/4)
Mussel single sample intactness proportional score			0.5
Mussel historical intactness percentage			
Mussel historical intactness class/metric score			
Mussel historical intactness proportional score			
Mussel taxonomic score			0.75
Integrity Score	0.5	0.775	0.85
Integrity Rating	C	B	B

Table 12. The number of datasets that contributed to final integrity ratings.

Datasets	Total Valley Segments
1	515
2	308
3	104
4	80
5	12
Total	1019

Table 13. The number of contributing sites to BSC ratings compared to the current number. The number of stream segments and/or streams with stream ratings or identification as a biologically significant stream and the percentage of the streams with A-E designations.

	BSC (1989)	BSC (1996)	BSS (1992)	Diversity Rating (2007)	Integrity Rating (2007)	BSS (2007)
# samples/sites	920			2493	2025	
# stream segments/valley segments	614			1127	1019	
# streams	478	746	132			122
% A	4	4.5		13	9	
% B	30	33.5		22	31	
% C	48	50		38	45	
% D	17	11.5		25	10	
% E	1	0.5		1	5	

Table 14. The underlying qualifications for designation as a biologically significant stream. All biologically significant streams have at least two datasets from differing taxonomic groups associated with them. For streams with A ratings either for diversity or integrity at least two datasets from different taxonomic groups had to contribute to the final rating. For streams that had the highest class/metric score the two different taxonomic groups could be derived from a combination of both the diversity and integrity datasets.

Rationale	Count
2+ highest classes but no A ratings	**54**
Total with A Rating	**68**
Total BSS valley segments	**122**
Breakdown 2+ highest class ratings	
Integrity A & 2+ highest classes	5
Diversity A & Integrity A & 2+ highest classes	11
Diversity A & 2+ highest classes	33
2+ highest classes but no A ratings	54
Total with 2+ highest classes	**103**
Breakdown A ratings	
Diversity A & Integrity A	1
Integrity A & 2+ highest classes	5
Diversity A	8
Integrity A	10
Diversity A & Integrity A & 2+ highest classes	11
Diversity A & 2+ highest classes	33
Total with A Rating	**68**

Table 15. Comparison of integrity classes from Karr *et al.*'s (1986) fish IBI, the Biological Stream Characterization (Bertrand *et al.* 1996), the revised fish IBI (Smogor 2000) and the corresponding scores.

Integrity Class (Karr *et al*. 1986)	**Fish IBI Score (Karr *et al*. 1986)**	**BSC Aquatic Resource Description and Letter Rating (Bertrand *et al*. 1996)**	**BSC Fish IBI score (Bertrand *et al*. 1996)**	**Revised Fish IBI class (Smogor 2000)**	**Revised Fish IBI Score (Smogor 2000)**
Excellent	58-60	Unique (A)	51-60	1	56-60
Good	48-52	Highly Valued (B)	41-50	2	46-55
Fair	40-44	Moderate (C)	31-40	3	31-45
Poor	28-34	Limited (D)	21-30	4	16-30
Very Poor	12-22	Restricted (E)	≤20	5	0-15

Figures

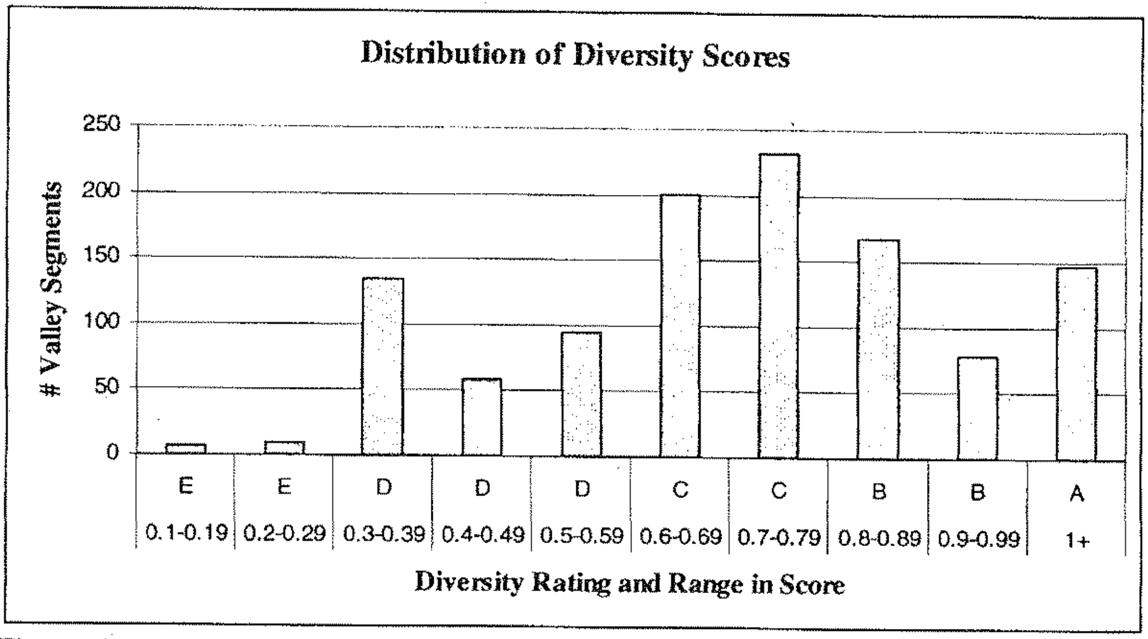

Figure 1. Distribution of diversity scores and corresponding letter rating. The percentage of valley segments with diversity ratings of A-E is 13, 22, 38, 25, and 1 respectively.

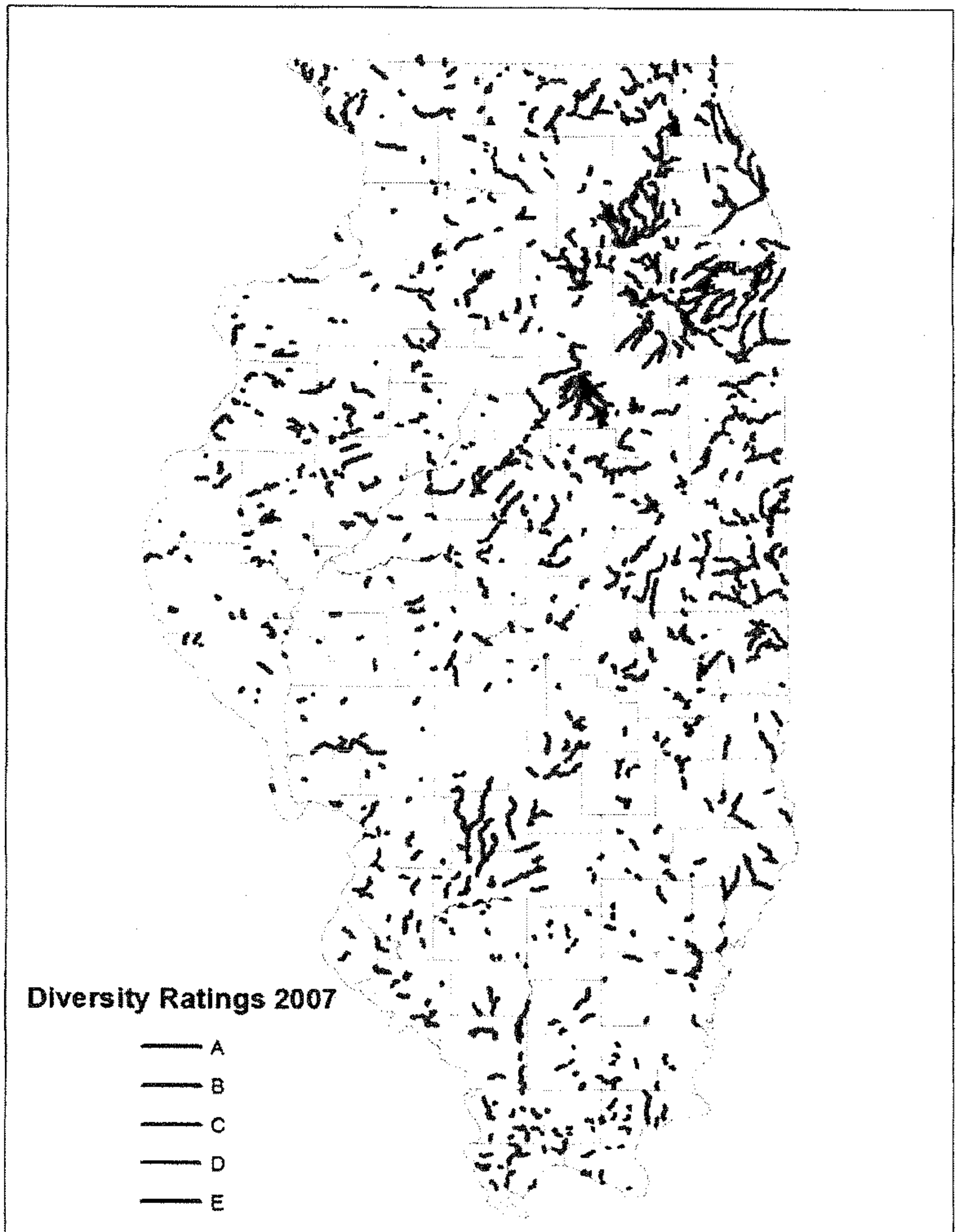

Figure 2. Geographic distribution of diversity ratings. Three percent of the total number of the valley segments for the state have a diversity rating.

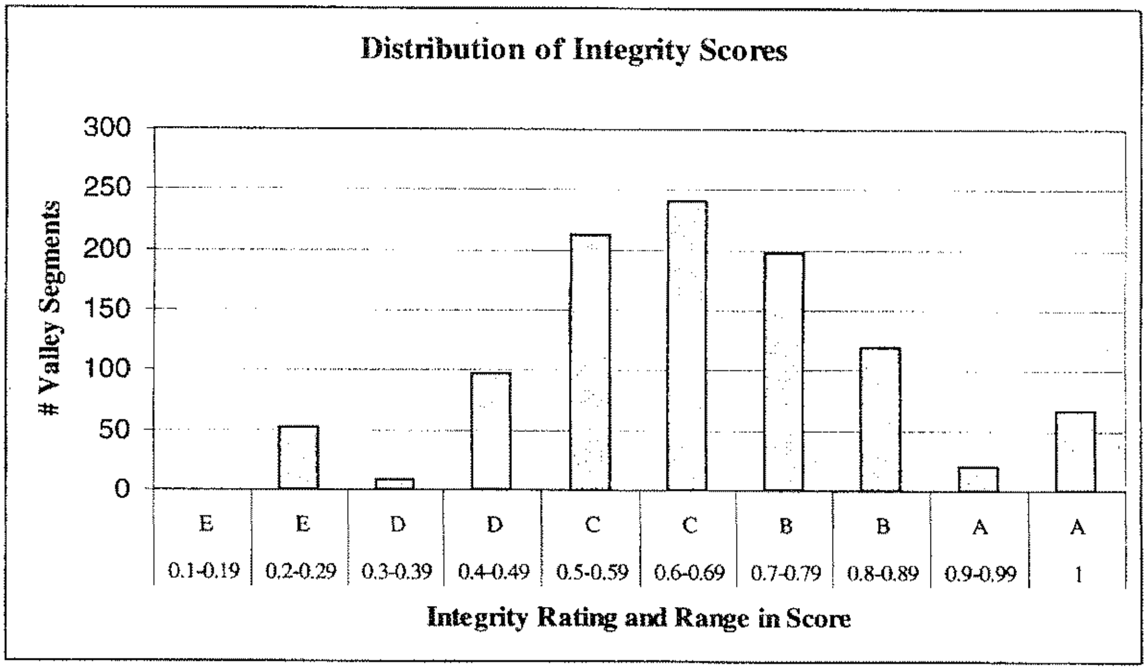

Figure 3. Distribution of integrity scores and corresponding letter rating. The percentage of valley segments with integrity ratings of A-E is 9, 31, 45, 10, and 5 respectively.

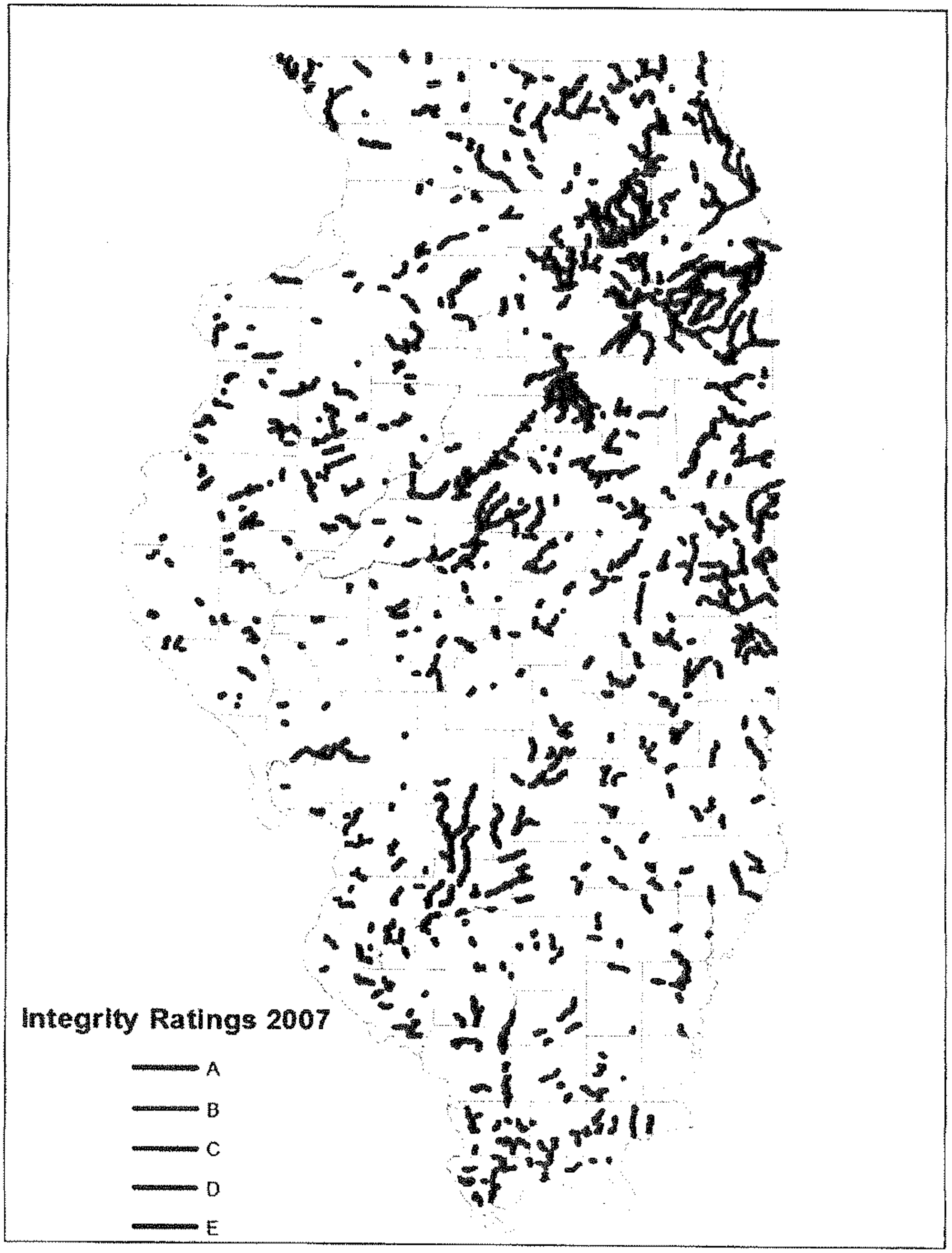

Figure 4. Geographic distribution of integrity ratings. Of the total 38046 valley segments for the state only 2.7% have an associated integrity rating.

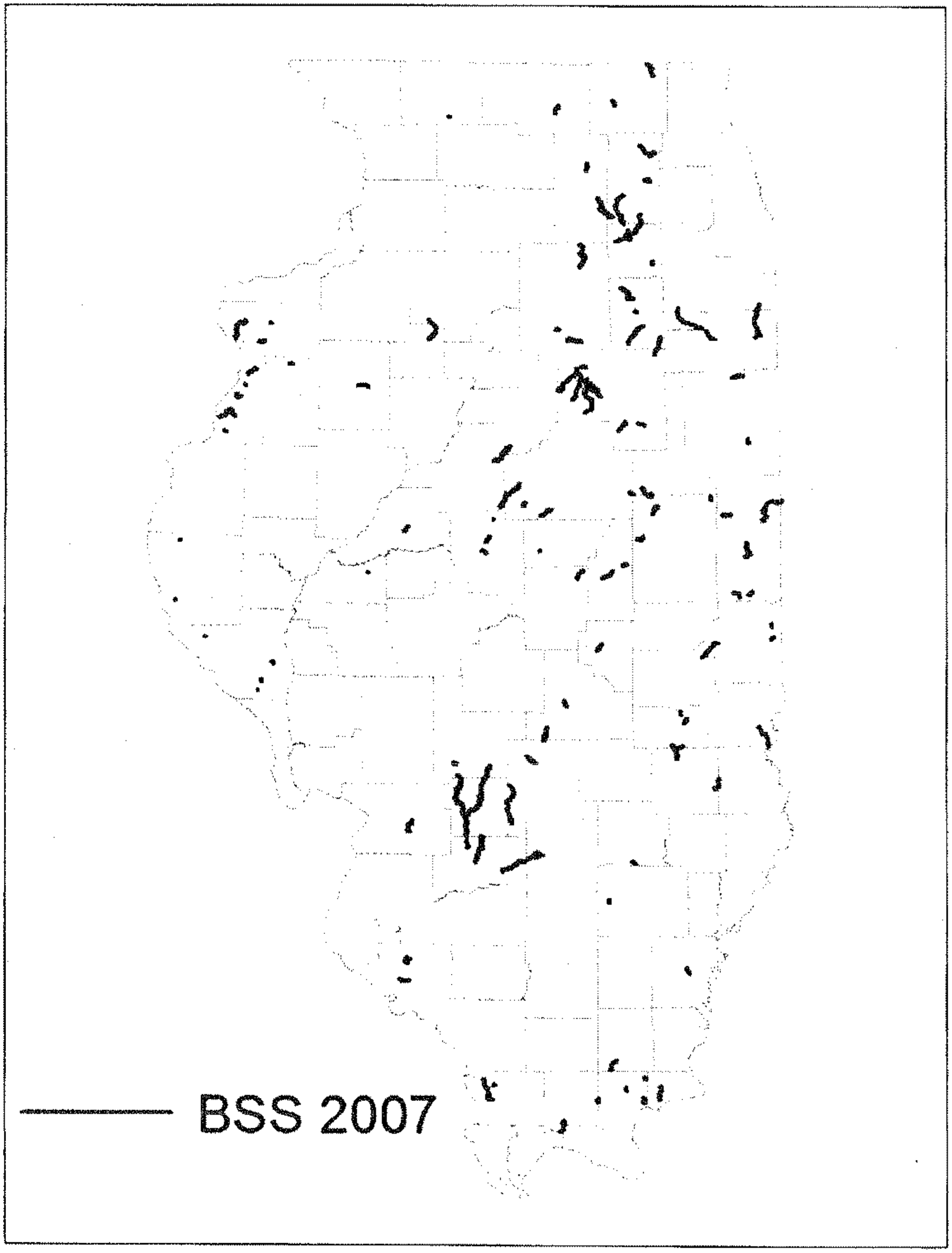

Figure 5. Geographic distribution of biologically significant streams. A total of 122 valley segments have been designated as BSS.

Appendix A

Biologically Significant Streams Workgroup Members

Name	Affiliation
Leslie Bol	INHS
Doug Carney	IDNR
Glynnis Collins	Prairie River Network
Joel Cross	IDNR
Kevin Cummings	INHS
Ed DeWalt	INHS
Ben Dolbeare	IDNR
John Epifanio	INHS
Albert Ettinger	Environmental Law and Policy Center
Bill Ettinger	IEPA
Bud Fischer	Eastern Illinois University
Gregg Good	IEPA
Jim Herkert	The Nature Conservancy
Leon Hinz	INHS
Jana Hirst	IDNR
Ann Marie Holtrop	IDNR
Stacy James	Prairie River Network
Brian Koch	IEPA
Brandon Koltz	IAWA
Glen Kruse	IDNR
Gary Lutterbie	IDRN
Nick Menninga	IAWA
Bob Mosher	IEPA
Steve Pescitelli	IDNR
Chris Phillips	INHS
Mike Retzer	INHS
Karen Rivera	IDNR
Ken Robertson	INHS
Robert Rung	IDNR
Randy Sauer	IDNR
Manju Sharma	IAWA
Matt Short	IEPA
Cindy Skrukrud	Sierra Club
Roy Smogor	IEPA
Scott Stuewe	IDNR
Bob Szafoni	IDNR

Chris Taylor	INHS
Jeremy Tiemann	INHS
David Thomas	INHS
Trent Thomas	IDNR
Matt Whiles	Southern Illinois University Carbondale
John Wilker	IDNR

Mussel Data Collectors

The collectors' data that were used included:

Collins E.
Corgiat D.
Cummings K. S.
Dunn H.
Kasprowicz B. J.
Kitchel H. E.
Schanzle R. W.
Schwegman J. E.
Sietman B. E.
Suloway L.
Szafoni R. E.
Tiemann J. S.
Wetzel M. J.

Appendix B

List of Threatened and Endangered Species included in Stream Ratings Project

Amphibians

Endangered

Spotted Dusky Salamander (*Desmognathus conanti*)

Crayfish

Endangered

Indiana Crayfish	*Orconectes indianensis*
Kentucky Crayfish	*Orconectes kentuckiensis*
Shrimp Crayfish	*Orconectes lancifer*
Bigclaw Crayfish	*Orconectes placidus*

Fish

Endangered

Lake Sturgeon	*Acipenser fulvescens*
Western Sand Darter	*Ammocrypta clarum*
Bluebreast Darter	*Etheostoma camurum*
Harlequin Darter	*Etheostoma histrio*
Cypress Minnow	*Hybognathus hayi*
Bigeye Chub	*Hybopsis amblops*
Pallid Shiner	*Hybopsis amnis*
Northern Brook Lamprey	*Ichthyomyzon fossor*
Sturgeon Chub	*Macrhybopsis gelida*
Greater Redhorse	*Moxostoma valenciennesi*
River Chub	*Nocomis micropogon*
Pugnose Shiner	*Notropis anogenus*
Bigeye Shiner	*Notropis boops*
Blacknose Shiner	*Notropis heterolepis*
Taillight Shiner	*Notropis maculatus*
Weed Shiner	*Notropis texanus*
Northern Madtom	*Noturus stigmosus*
Pallid Sturgeon	*Scaphirhynchus albus*

Threatened

Eastern Sand Darter	*Ammocrypta pellucidum*
Longnose Sucker	*Catostomus catostomus*
Cisco	*Coregonus artedi*
Gravel Chub	*Erimystax x-punctatus*
Iowa Darter	*Etheostoma exile*
Banded Killifish	*Fundulus diaphanus*
Starhead Topminnow	*Fundulus dispar*
Least Brook Lamprey	*Lampetra aepyptera*

Redspotted Sunfish	*Lepomis miniatus*
Bantam Sunfish	*Lepomis symmetricus*
River Redhorse	*Moxostoma carinatum*
Ironcolor Shiner	*Notropis chalybaeus*
Blackchin Shiner	*Notropis heterodon*

Mussels

Endangered

Spectaclecase	Cumberlandia monodonta
Fanshell	Cyprogenia stegaria
Snuffbox	Epioblasma triquetra
Pink Mucket	Lampsilis abrupta
Wavy-rayed Lampmussel	Lampsilis fasciola
Higgins Eye	Lampsilis higginsii
Orangefoot Pimpleback	Plethobasus cooperianus
Sheepnose	Plethobasus cyphyus
Clubshell	Pleurobema clava
Ohio Pigtoe	Pleurobema cordatum
Fat Pocketbook	Potamilus capax
Kidneyshell	Ptychobranchus fasciolaris
Rabbitsfoot	Quadrula cylindrica
Salamander Mussel	Simpsonaias ambigua
Purple Lilliput	Toxolasma lividus
Rainbow	Villosa iris

Threatened

Slippershell	*Alasmidonta viridis*
Purple Wartyback	*Cyclonaias tuberculata*
Butterfly	*Ellipsaria lineolata*
Elephant-ear	*Elliptio crassidens*
Spike	*Elliptio dilatata*
Ebonyshell	*Fusconaia ebena*
Black Sandshell	*Ligumia recta*
Little Spectaclecase	*Villosa lienosa*

Plants

Heart-leaved Plantain (*Plantain cordata*)

0

Illinois Department of Natural Resources
Office of Resource Conservation

Integrating Multiple Taxa in a Biological Stream Rating System

March, 2008

Acknowledgments

This work would not have been possible without the previous efforts of the Biological Stream Characterization Work Group that instituted a statewide stream rating system in the late 1980s or our predecessors at the Illinois Natural History Survey that developed the initial Biologically Significant Streams listing. We would like to thank all the members of our Biologically Significant Streams work group for their efforts at enhancing this project. Special thanks to Kevin Cummings, Ed DeWalt, Mark Joseph, Christine Mayer, Chris Phillips, Bob Schanzle, Bob Szafoni, Chris Taylor, John Wilker, and the IDNR stream specialists for providing access to data from streams throughout Illinois. Funding was provided to the Illinois Natural History Survey through Illinois' State Wildlife Grant Program (T-20-P-001).

Preface

For over twenty years, resource mangers in Illinois have used stream biological ratings as a vehicle for the interpretation, assessment, and communication of aquatic resource values. The first stream ratings, published in 1989, were based on a five-tiered classification system predicted largely on the type and condition of the fishery resource. In July 2005, the State of Illinois submitted a Comprehensive Wildlife Conservation Plan to the U. S. Fish and Wildlife Service as part of a Congressional mandate to be eligible for future federal funding. The plan was accepted, renamed the Illinois Wildlife Action Plan, and became the strategic document guiding protection and conservation efforts throughout the state. As the name implies, the Illinois Wildlife Action Plan outlines a plan of action to address the particular needs of wildlife that are declining and presents a targeted approach to habitat enhancement and conservation. The Wildlife Action Plan broadly addresses all types of wildlife including fish, mussels, amphibians, and reptiles. To help establish baseline conditions against which change promoted by the Illinois Wildlife Action Plan could be measured and understood, the following report describes in detail a stream rating process based on multiple aquatic taxonomic groups. Users desiring access to the most current ratings and additional location information are encouraged to search http://dnr.state.il.us/biologicalstreamratings. The ratings will provide the Illinois Department of Natural Resources with a mechanism for identifying high-quality examples of all stream communities and will guide management and restoration activities throughout the state.

The State of Illinois owns the wildlife and aquatic resources residing with its borders (see 515 ILCS 5-5 and 520 ILCS 5/2.1). The Illinois Department of Natural Resources is designated in state law as the agency of state government charged with the regulation protection and preservation of those natural resources. The Illinois Department of Natural Resources is also charged with conduct of research, data collection and dissemination on matters related to natural resources of this state. IDNR has committed staff and resources to the development of tools to facilitate its preservation responsibilities. Tools like plans and stream ratings studies become the basis for field program implementation for resource protection.

Biological Ratings for Illinois Streams

List of Tables

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Introduction

Comprehensive statewide biological, chemical, and physical information associated with streams in Illinois has been routinely collected since 1980 through a partnership between the Illinois Department of Natural Resources (IDNR) and the Illinois Environmental Protection Agency (IEPA; Bertrand *et al.* 1996). This partnership was established in order to assess fish and macroinvertebrate communities, water quality, and habitat throughout major basins of Illinois. In 1984, a Biological Stream Characterization (BSC) Work Group was convened to create a mechanism for interpreting data collected as part of the interagency Basin Survey Program, and "to provide managers an overall prospective of the state's stream resources" (Hite and Bertrand 1989). The BSC Work Group developed stream ratings using letter grades "A" through "E", thereby establishing a means of communicating the quality of biological resources in streams to diverse stakeholders.

At the time the BSC Work Group began, the fish-based Index of Biotic Integrity (IBI) was recently developed, and it became the predominant stream integrity indicator used for rating streams (Hite and Bertrand 1989). In recognition of the need to also protect other stream-dependent organisms in the state, the Illinois Natural History Survey (INHS) developed a list of Biologically Significant Streams (BSS) that incorporated data on mussel communities and rare species (endangered, threatened, watch list) of crustaceans, fish, mussels, and aquatic plants in addition to stream segments rated as "A" by the initial BSC (Page *et al.* 1992). The goal of the BSS project was to protect 100% of the stream-dependent biodiversity, thus a stream with characteristics that met any one of the established criteria could achieve status as a BSS (Page *et al.* 1992). Despite the lack of regular updates, the BSC and BSS processes generated products that are still used extensively by diverse stakeholders including state and federal agencies, local watershed groups, consultants, environmental interest groups, and municipalities.

In 2006, the IDNR initiated an effort to combine and update the previous stream rating efforts into a single rating. The purpose behind the project was not only to update outdated information (i.e., the existing ratings were based on data at least 15 years old) but to create a rating system that would help resource mangers determine efficacy in implementing the aquatic goals of the Illinois Wildlife Action Plan (State of Illinois 2005). To be most useful in evaluating and guiding implementation of the Wildlife Action Plan, IDNR sought a single rating for stream segments that represented multiple signals of stream condition. This intent was similar to the "overall prospective" identified by Hite and Bertrand (1989). Although the main purpose behind stream ratings has changed since the creation of BSC and BSS, several other objectives for the development and use of ratings remain. These include:

- Facilitate planning and prudent allocation of State resources in IDNR monitoring activities;
- Inventory and identify the nature, extent, and distribution of Illinois stream resources;

- Establish a common vehicle for the interpretation, assessment, and communication of aquatic resource values;
- Identify stream segments exhibiting a high potential for resource management or restoration activities;
- Focus greater emphasis on the importance of uncommon aquatic biotic resources and an awareness of where these resources exist.

Since BSC and BSS were developed, the quantity and quality of aquatic data and assessment tools has increased. For example, multi-metric indices have been developed for benthic macroinvertebrates (Tetra Tech, Inc. 2007) and mussels (Szafoni 2002), and revised for fish (Smogor 2000). Further, the Basin Survey Program, which assesses fish and macroinvertebrate communities, has continued. These available indices and data presented new opportunities to create a rating that reflects how different taxonomic groups can respond dissimilarly to shared stream conditions because of differences in life-history, mobility, and sensitivities to stressors (Paller 2001). Specifically in this project we used fish, macroinvertebrate, and mussel information because these taxa reflect steam conditions at different spatial and temporal scales (Diamond and Serveiss 2001, Freund and Petty 2007, Kilgour and Barton 1999, Lammert and Allan 1999). For instance, due to their limited mobility, typically shorter life spans, and association with stream substrate, macroinvertebrates may be indicators of local and more recent stream conditions (Freund and Petty 2007), whereas fish may be better indicators of regional conditions because they have greater movement capabilities and longer life cycles. Mussels, due to their limited dispersal as adults, may also indicate local conditions, but due to longer life spans may reflect historic stressors related to specific areas (Diamond and Serveiss 2001). By incorporating various taxonomic groups and averaging standardized taxonomic scores, we generated an overall rating for stream segments that is representative of multiple signals of stream conditions. This report describes an approach that results in assigning up to three designations for a stream segment, which are a diversity rating, integrity rating, and identification as a biologically significant stream.

General Approach for Diversity and Integrity Ratings

Several purposes of the previous BSC and BSS processes overlapped between the two initiatives. Both had objectives to identify the extent of Illinois stream resources, to identify stream segments of exceptional quality, and to focus protection efforts toward uncommon resources or biologically significant streams (Bertrand *et al.* 1996, Page *et al.* 1992). However, the two initiatives differed in their overall intent to rate a stream's biological diversity (Page *et al.* 1992) or biological integrity (Bertrand *et al.* 1996; Hite and Bertrand 1989). For the purposes of implementing Illinois' Wildlife Action Plan, IDNR sought a rating system that would include both diversity and integrity measures. Although the approach to obtain the diversity and integrity ratings is similar, we have not directly combined the two ratings for an overall rating. Diversity and integrity ratings were kept separate because it is possible to have highly intact communities that are not biologically very diverse. For instance, species richness expectations for small or cold-water streams are expected to be low compared with larger or warmer streams. Therefore, it is possible to have a small stream that would rate high for integrity but low for diversity. Additionally, keeping the two ratings separate enables stakeholders with different purposes to consider the rating that is most applicable to their needs. The letter ratings of A-E were maintained for both the diversity and integrity ratings as these designations were used in the previous BSC revision.

Given the change in focus and use for this project from previous stream ratings, we considered several aspects of the previous rating processes and modified the process accordingly. Because multiple data sources are used to generate a rating, there was a need to standardize data from different sources in an effort to give equal weight to all communities of organisms found in streams if adequate and comparable sampling had occurred. Second, we sought a data driven and reproducible process that did not include narrative information (see Hite and Bertrand 1989 and Bertrand *et al.* 1996 for an explanation of how narrative information was used previously). Third, we envisioned a product that could be easily updateable as new information became available.

The general approach for obtaining a diversity or integrity rating is a six step process:

1. Select data for inclusion in the rating.
2. Convert raw data to a class score.
3. Standardize classes into a proportional score (P score).
4. Average the proportional scores within a given taxonomic group to obtain a single taxonomic score (T score).
5. Average proportional and/or taxonomic score for multiple sites on a valley segment.
6. Determine the final diversity and/or integrity rating for a valley segment.

We considered all the information that contributed to both integrity and diversity ratings in order to identify Biologically Significant Streams. Similar to the initial BSS effort, we incorporated multiple datasets and identified streams based on available taxonomic groups rather than relying on the fish data as the primary stream integrity indicator. However, unlike the additive approach of the original BSS that identified all reaches with appropriately high fish IBI data, mussel species richness, or threatened and endangered species presence regardless of what other available information may have indicated, the current process uses a holistic approach that combines data sources to determine if the biologically significant stream designation is appropriate.

Fish, mussel, macroinvertebrate, crayfish, and threatened and endangered species data collected by various state agencies were used for stream ratings. All datasets were overlaid on the 1:100,000 – scale, National Hydrography Dataset (NHD; USGS 2000) that was refined for a previous project (Holtrop and Dolan 2003). Point locations of data that were greater than 60m from the nearest digitized stream line were visually inspected using an overlay of aerial images to determine if the point was associated with a large river or a small stream that was not digitized. Points that were associated with large rivers and undigitized streams were separated into a different file and omitted from further analysis. Points that did not fall into either of these categories were further investigated to determine if there was an error with the spatial coordinates. Errors were remedied where possible, and points that could not be corrected and still fell greater than 60m from the nearest stream were omitted.

Point data or sampling sites for the final ratings were summarized according to valley segment. Valley segments are aggregations of linearly adjacent, physically similar stream reaches (Seelbach *et al.* 1997). Physical characteristics used to define valley segments were related to stream size (drainage area), surficial geology (bedrock, coarse substrates), discharge (flow yield), and gradient. Valley segments were independently derived prior to this project using a spatially-constrained clustering method based on the cluster affinity search technique (Brenden *et al.* in press). Valley segment numbers were assigned to datasets through a spatial join in ArcMap 9.2. Datasets were then associated with each other for calculation of the final rating according to valley segment number in a query performed in Microsoft Office Access 2003.

Diversity Ratings

Background
Diversity simply defined is the number of different kinds of things (Angermeier and Karr 1994) or the variety of life and its processes (Hughes and Noss 1992). Although diversity can be represented mathematically using summary indices or a simple species number, we chose to consider it more broadly as the variety of taxa within several important aquatic groups (e.g., mussels, fish, macroinvertebrates, and crayfish). In December 2006, project stakeholders met and discussed the appropriateness of available datasets for inclusion in the diversity analysis. We considered data collected within the past decade (1997-2006) that were collected as part of IDNR, IEPA, or INHS monitoring programs. We limited data to these institutions to ensure that collection methods were standardized, repeatable, and will be continued in the future so that data will be available for revisions of these ratings.

Approach
The general approach for obtaining a diversity rating is a six step process.

Step 1. Select data for inclusion into the rating.

We considered only data that were collected within the past decade. However, if a single site had more than one sample from the past decade, we used the sample with the highest richness for inclusion in the final rating calculation. We used this approach rather than taking the most recent sample or an average of the samples because the highest richness represents a conservative estimate of the biological potential for the site and this approach accounts for variation that may occur with sampling. Additionally, we did not average the data from multiple samples since the average could represent a condition that had not been found at the site. The following data were used in the final diversity ratings.

Fish – Fish data from community samples taken as part of cooperative basin surveys and other department monitoring were provided by the IDNR. These data were reviewed by regional IDNR stream biologists for verification that the samples were representative of community samples with adequate sampling efficiency. The species richness metric was retrieved from the Index of Biotic Integrity (IBI; Smogor 2000) summaries and was used as a component of the diversity rating. A total of 731 sites were used in the diversity score analysis (Table 1). There were fewer sites with fish species richness than fish IBI scores since the individual metrics scores used to calculate the fish IBI were not always available.

Aquatic Macroinvertebrates – Data for aquatic macroinvertebrates were compiled from three different entities.

<u>Macroinvertebrate Taxa Richness</u>
First, benthic macroinvertebrate data were compiled from the IEPA in Springfield. These data were collected following protocols established for use in the Stream Condition Index

(Tetra Tech, Inc. 2007), but referred to as the Macroinvertebrate Index of Biotic Integrity (MIBI) in this report. The taxa richness metric was retrieved from the MIBI, and a total of 452 sites were used for the final diversity score analysis (Table 1).

Critical Trends Assessment Program (CTAP)
Second, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddis flies; EPT) data that were collected since 1997 as part of CTAP (http://ctap.inhs.uiuc.edu/index.asp) were obtained. Although the MIBI contains an EPT richness metric, the CTAP data were used because these data were collected in the spring of the year prior to the emergence of many of these species and also typically on smaller streams than those included in the IEPA sampling. A total of 179 sites were used for the final diversity score analysis (Table 1).

S1S2 EPT
Third, we included information on sensitive Ephemeroptera, Plecoptera, and Tricoptera data provided by Dr. Ed DeWalt (INHS). These data were included because currently no EPT species are listed as endangered or threatened by the Illinois Endangered Species Protection Act (http://dnr.state.il.us/espb/datelist.htm), although some species within these orders have been identified as critically imperiled (S1) or imperiled (S2) at the state level by an INHS entomologist (DeWalt *et al.* 2005, Favret and DeWalt 2002). S1S2 refers to conservation status ranks used by NatureServe (http://www.natureserve.org/). A total of 104 sites were used for the final diversity score analysis (Table 1).

Mussels – Mussel data were obtained from the INHS mollusk collections database (http://www.inhs.uiuc.edu/cbd/collections/mollusk/molluskintro.html) and IDNR. Records associated with freshwater snails, fingernail clams, zebra mussels, and Asian clams were not included, as well as any records not associated with stream habitat. In order to query data that were representative of community samples, we restricted our data to a list of collectors' names obtained from Kevin Cummings, the INHS malacologist and mussel database manager. A total of 596 sites were used for the final diversity score analysis (Table 1).

Crayfish – Native crayfish data were obtained from the INHS crustacean collection database (http://www.inhs.uiuc.edu/cbd/collections/crustacean/crustaceanintro.html). Despite the lack of systematically collected crayfish data across the state, we included crayfish in a limited capacity in the final diversity ratings because they are abundant in Illinois streams and we anticipate that additional collections will be available for future updates of stream ratings. A total of 18 sites were used for the final diversity score analysis (Table 1).

Threatened and Endangered Species – Data on threatened and endangered (T&E) fish, mussel, crayfish, amphibian, and plant species (see Appendix B for species lists) were extracted from the Biotics Database maintained by the IDNR Office of Resource Conservation, Division of Natural Heritage. A total of 413 sites with T&E species were used for the final diversity score analysis (Table 1).

Table 1. The number of sites from each data source used to calculate diversity ratings.

Potential Data Source	Number of Sites
Fish Species Richness	731
Macroinvertebrate Taxa Richness	452
CTAP EPT Species Richness	179
S1S2 EPT Species Richness	104
Mussel Species Richness	596
Crayfish Species Richness	18
Threatened and Endangered Species Richness	413
Total	2493

Step 2. Convert raw data to a class score.

One of the objectives for this project was to give equal weight to all communities of organisms found in streams if adequate and comparable sampling had occurred. To do this, we developed classes for each dataset used in the analysis in an attempt to interpret raw data from different sources and classify it similarly. Classes were independently developed for each dataset using each sample collection as an independent record rather than pooling samples from a single site. For example, if one site had multiple samples collected between 1997-2006, then each sample was treated as an independent record for the purpose of creating the class scores. Therefore, richness expectations were based on the number of species you would expect to find in a single sampling event. Once the classes were established, only the sample that had the highest richness from each site was used to calculate the final diversity rating.

Fish Species Richness — The fish species richness metric was retrieved from the Index of Biotic Integrity (IBI; Smogor 2000) summaries and was used as a component of the diversity rating. We used the classes developed for IBI because they accounted for variation in fish species richness expectations across different sized streams, slope, and region. We maintained these classes with a single modification. In the IBI, fish richness metric scores range from 0-6. Because the "0" does not represent a true absence of fish, we added "1" to each class thereby resulting in class scores from 1-7.

Macroinvertebrate Taxa Richness — The MIBI did not have classes associated with individual metrics; however the availability of least-disturbed samples provided the opportunity to define classes for macroinvertebrate taxa richness by using the same approach that was used to define classes for individual metrics within the fish IBI (Smogor 2000). The top class for taxa richness was set at the 75^{th} percentile of reference sites. Using this approach, taxa richness values for MIBI ranged from 0 to 35+ and were placed into seven classes (Table 2). Data were not further stratified by stream size or location because previous analysis determined that neither affected taxa richness expectations (Tetra Tech, Inc. 2007).

Table 2. Number of taxa corresponding to the 7 classes developed for the MIBI.

Class Score	Taxa Richness
7	35+
6	31-34
5	25-30
4	19-24
3	13-18
2	7-12
1	0-6

CTAP EPT Species Richness — In order to maintain similarity across data sources, we used the 90th percentile as the boundary for the highest class for datasets that were not developed with a reference site approach (i.e., mussels, CTAP EPT macroinvertebrates, S1S2 macroinvertebrates, crayfish, and threatened and endangered species). Our rationale was that by raising the standard for the top class for these datasets to at least the 90th percentile, the highest class would be similarly restrictive as the datasets that did have reference site data available. Using the 90th percentile as the cut for the top class, three classes were created (Table 3).

Table 3. Number of species corresponding to the three classes developed for the Critical Trend Assessment Program's Ephemeroptera, Plecoptera, and Tricoptera data. The species from the three orders are considered together.

Class	Percentile	Number of Species
1	<50th	1-8
2	50th – 89th	9-18
3	90th +	19+

Mussel Species Richness — A mussel species richness of ten species or greater was previously used to identify BSS (Page *et al.* 1992) and was also used as the threshold for defining the highest classification for the species richness factor in the Illinois Mussel Classification Index (Szafoni 2002; MCI). However, we investigated the relationship among mussel species richness across different sized streams defined by steam link (Shreve 1967) within different drainages and subsequently adopted new class scores based on our analysis. Three classes were developed for mussel species richness expectations for each of the major drainages based on the percentiles within three stream size groupings of the tributary streams and the mainstem (Table 4). Class one consisted of samples that were below average richness within the drainage (0-49th percentile), class two were above average samples (50-89th), and class three were exceptionally high scoring samples (90th percentile and above (Table 4)).

Table 4. Mussel species richness ratings based on expectations according to drainage and stream size. Stream size is defined by link number, which is the number of first order streams based on the 1:100,000 National Hydrography Dataset (NHD) upstream of a given stream reach. Link codes refer to groupings of link numbers.

Stream Size	Drainage	Class 1 (<50th percentile)	Class 2 (50th-90th percentile)	Class 3 (90th percentile +)
Small (Link code 1)	Illinois	<3	3-7	8+
	Mississippi	<2	2-5	6+
	Ohio	1	2	3+
	Wabash	<3	3-8	9+
Medium (Link code 2-3)	Illinois	<5	5-11	12+
	Mississippi	<5	5-10	11+
	Ohio	<2	2-3	4+
	Wabash	<5	2-10	11+
Large (Link code 4-6)	Illinois	<5	5-11	12+
	Mississippi	<7	5-11	12+
	Ohio	<2	2-5	6+
	Wabash	<6	6-13	14+
Mainstem (Link code 7)	Illinois	<9	9-10	11+
	Mississippi	<15	15-20	21+
	Ohio	<6	6-13	14+
	Wabash	<3	3-9	10+

Bonus Points – The final diversity rating also integrates information about taxa that were deemed important due to their rarity. The S1S2 EPT, Crayfish, and T&E datasets had a limited range of data and subsequently were used differently in the final ratings than other fish, macroinvertebrate, and mussel data described previously. The rationale for this is described in steps 4 and 6 below. Class scores for these three datasets were based on percentiles, but were adjusted in weight based on how these data were added to the diversity rating.

Step 3. Standardize classes into a proportional score (P score).
All class scores range from "1" to a greater number with the greatest number always representing the highest class. In this step, we divided the assigned class score by the total number of classes available to obtain a proportional score (P score), which has a maximum of 1. For example, a site that had 26 macroinvertebrate taxa falls in class 5, which equates to a P score of 5/7 (0.714). Proportional scores were used to standardize differing numbers of classes among variables.

Step 4. Average the proportional scores for the three different macroinvertebrate datasets in order to obtain a single taxonomic score (T score).

When multiple datasets (i.e., taxa richness from MIBI, EPT richness from CTAP, and S1S2 EPT species) were available for macroinvertebrates, the average of the proportional scores was used to determine the taxonomic score (i.e., macroinvertebrate taxonomic score). Creating a taxonomic score allowed us to include information derived from separate assessments into a combined signal for macroinvertebrates. However, we averaged all available macroinvertebrate information into a taxonomic score rather than keeping the datasets separate and averaging them all into a final score in order to give equal weight to fish, macroinvertebrates, and mussels in the final diversity rating.

S1S2 EPT data were added to the macroinvertebrate taxonomic score as bonus point data rather than averaged into the taxa score in order to ensure that the presence of these sensitive taxa always improved a stream rating. The maximum number of bonus points was awarded to samples with three or more species as this corresponds to the 90th percentile for the number of species found per sample. Samples with 1-2 species are awarded half the maximum. The diversity score prior to adding bonus points is based on the average of the macroinvertebrate taxonomic score, the fish proportional score and the mussel proportional score. Since the macroinvertebrate taxonomic score is potentially 1/3 of the overall diversity score, and S1S2 EPT potentially contribute 1/3 to the macroinvertebrate taxonomic score, the S1S2 EPT data potentially contribute 1/9th (0.11) of the pre-bonus points diversity score. We therefore, assigned 0.11 for samples with 3+ and 0.055 for 1-2 species.

Some valley segments had S1S2 EPT data available but lacked other macroinvertebrate data. In these cases we added the bonus points after the fish and mussel taxonomic scores had been averaged (Step 5). However, since the data were added at a different point in the process, the bonus points were divided by three since they would contribute to a third of the diversity score prior to the T&E and Crayfish bonus points being added. Therefore, for valley segments without other macroinvertebrate data, 0.037 was added when there were 3+ species and 0.018 for samples with 1-2 species.

Step 5. Average proportional and/or taxonomic score for multiple sites on a valley segment.

When multiple sites were associated with a particular valley segment within a dataset, the average of these proportional or taxonomic (for macroinvertebrates) scores was used to calculate the final diversity score. An average from the different sites was used rather than considering the highest proportional score from the valley segment since conditions within the stream segment may vary between sites and an average for the whole valley segment was a better representation than the signal from a single site.

Step 6. Determine the final diversity rating for a valley segment.

The final diversity score is based on five potential data sources: average of the fish proportional scores available for the valley segment, average of the mussel proportional scores available for the valley segment, the average macroinvertebrate taxonomic scores, as well as crayfish and T&E species richness.

Threatened and Endangered Species (T&E)

Threatened and endangered species (T&E) data were added to the diversity score after the fish proportional scores, mussel proportional scores, and macroinvertebrate taxonomic scores have been averaged. Because T&E species were one of five potential values contributing to a final diversity rating, the 95th percentile of T&E values (i.e., 2+ species) was awarded 0.2 (1/5) bonus points. Sites having one T&E species were awarded 0.1 bonus points. The maximum points T&E species could add to a final diversity score was 0.2, even if more than one sample for a given valley segment had 2+ T&E species.

Crayfish

Similarly to T&E species, crayfish are added as bonus points after available fish, macroinvertebrate, and mussel information had been averaged. However, bonus points for crayfish were only awarded to samples that had three or more species. Three or more species represented the 95th percentile of available data and resulted in 0.1 bonus points.

The final diversity score is calculated as:

Diversity Score = average (average fish species richness P scores + average mussel species P scores + average macroinvertebrate T Scores) + threatened and endangered species bonus points + crayfish bonus points, where P score = proportional score and T score = taxonomic score.

Examples of Diversity Ratings

To further illustrate the diversity process we present several examples (Table 5). In the first example, only one dataset is associated with the valley segment. The fish species richness is 15, which corresponds to a class score of 5. To obtain the proportional score, 5 is divided by the total number of classes which is 7. Since there are no other datasets to average with the fish species richness the final diversity score is the same as the fish proportional score. A final diversity score of 0.714 equates to a letter rating of C.

In the second example data are available from three taxonomic groups. The fish species richness is 22, which equates to a class score of 6 and a proportional score of 0.857. The mussel species richness is 6, which equates to a class score of 2 and a proportional score of 0.667. The macroinvertebrate taxa richness is 42, which equates to a class score of 7 and a proportional score of 1. The diversity score is determined by averaging these three proportional scores. The final score of 0.841 corresponds to a letter rating of C.

The third example has two sets of macroinvertebrate data as well as fish and mussel data. The fish species richness is 10, equating to a class score of 3 and a proportional score of 0.429. The mussel species richness is 1, equating to a class score of 1 and a proportional score of 0.333. The macroinvertebrate taxa richness is 31 equating to a class score of 6 and a proportional score of 0.857. The CTAP EPT species richness is 17 equating to a class score of 2 and a proportional score of 0.667. Before the diversity score can be calculated, available macroinvertebrate data are combined into a taxonomic score. The macroinvertebrate taxonomic score is determined by averaging the macroinvertebrate taxa richness proportional score and the CTAP EPT proportional score. The final diversity score (0.51 with a diversity rating of D) is calculated by averaging the fish and mussel proportional scores and the macroinvertebrate taxonomic score.

Diversity Score = (0.429 + 0.333 + ((0.857 + 0.667)/2))/3+ 0 bonus points = 0.51

The fourth example also has two datasets available for macroinvertebrates. However, one of the datasets is S1S2 EPT bonus data. The CTAP ETP species richness is 20 representing a class score of 3 and a proportional score of 1. There is one S1S2 EPT species associated with the valley segment awarding 0.055 bonus points. The macroinvertebrate taxonomic score is therefore the CTAP EPT proportional score plus the S1S2 EPT bonus points. Since no other data are available the final score is equal to the macroinvertebrate taxonomic score (1.055 with a diversity rating of A).

The final example illustrates the procedure for dealing with valley segments that may have more than one sampling site associated with them and how to calculate the final diversity score using threatened and endangered species bonus points. The fish species richness is 33 equaling a class/metric score of 7 and a proportional score of 1. There are two mussel sites associated with the valley segment with species richness of 1 and 13. These correspond to class/metric scores of 1 and 3. To determine the final proportional score for the mussels the average is taken of the two site proportional scores. The fish and mussel proportional scores are then averaged before bonus points are awarded. Two threatened and endangered species are associated with the valley segment equating to 0.2 bonus points. Once these are added to the pre-bonus point diversity score of 0.889 the final diversity score is 1.089 with an A rating.

Table 5. Examples of calculating diversity scores.

	Example with single dataset	**Example with three taxonomic groups**	**Example with two macroinvertebrate datasets**	**Example with S1S2 EPT bonus points**	**Example with two mussel sites and threatened and endangered species bonus points**
Valley Segment	21679	39073	37913	3557	44269
Fish Species Richness	15	22	10		33
Fish species richness class score	5	6	3		7
Fish proportional score	0.714 (5/7)	0.857 (6/7)	0.429 (3/7)		1 (7/7)
Mussel species richness		6	1		1 and 13
Mussel species richness class score		2	1		1 and 3
Mussel proportional score		0.667 (2/3)	0.333 (1/3)		0.667 (average of 0.33 and 1)
Macroinvertebrate taxa richness		42	31		40
Macroinvertebrate taxa richness class score		7	6		7
Macroinvertebrate taxa richness proportional score		1 (7/7)	0.857 (6/7)		1 (7/7)
CTAP EPT species richness			17	20	
CTAP EPT species richness class score			2	3	
CTAP EPT species richness proportional score			0.667 (2/3)	1 (3/3)	
S1S2 EPT specie richness				1	
S1S2 EPT specie richness bonus points				0.055	
Macroinvertebrate taxonomic score		1	0.76	1.055	1
Pre-bonus points Diversity score	0.714	0.841	0.51	1.055	0.889
Crayfish species richness					
Crayfish species richness bonus points					
Threatened and Endangered species richness					2
Threatened and Endangered species richness bonus points					0.2
Final Diversity Score	0.714	0.841	0.51	1.055	1.089
Diversity Rating	C	B	D	A	A

The cut-offs for the final diversity letter ratings were determined by visually inspecting the distribution of the diversity scores (Figure 1). We also attempted to have a similar percentage of valley segments within each letter category as the previous BSC projects. A total of 1127 valley segments were assigned a diversity rating of A-E (Figure 2). This represents 3% of the total 38046 valley segments that exist for the state of Illinois. Of the valley segments that were rated, the percentage with the assignment of the ratings A-E is 13, 22, 38, 25 and 1 respectively. While this procedure has been developed for assigning ratings using multiple datasets, approximately one half of the total valley segments that were rated had data available from only one dataset (Table 6).

Table 6. The number of datasets that contributed to final diversity ratings.

Datasets	Total Valley Segments
1	565
2	370
3	134
4	44
5	11
6	3
Total	1127

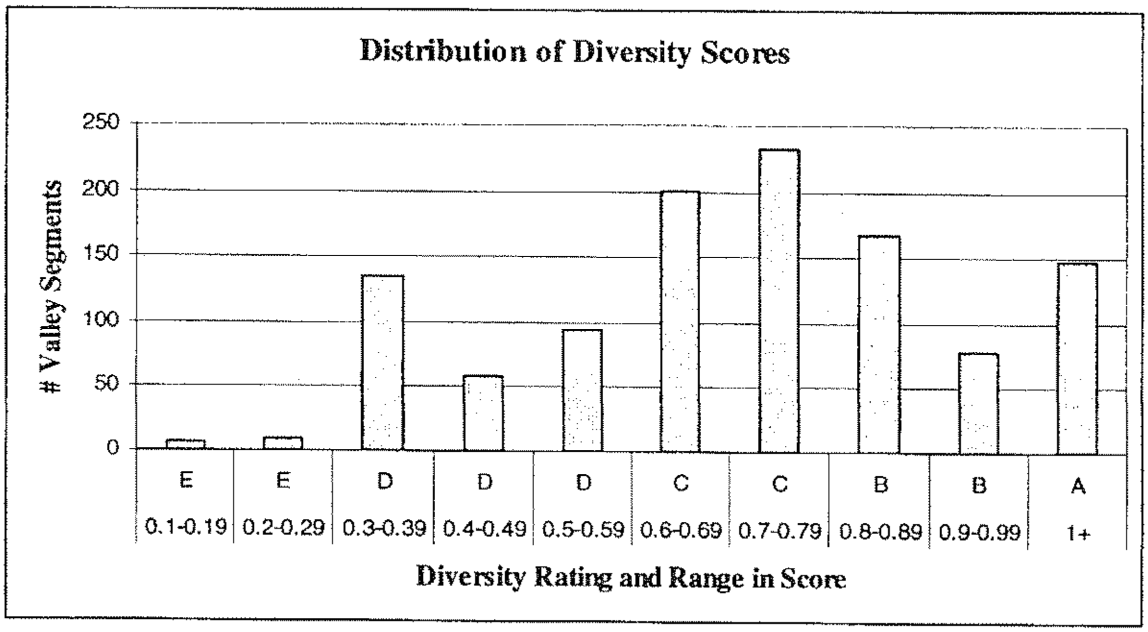

Figure 1. Distribution of diversity scores and corresponding letter rating. The percentage of valley segments with diversity ratings of A-E is 13, 22, 38, 25, and 1 respectively.

Map of Diversity Ratings

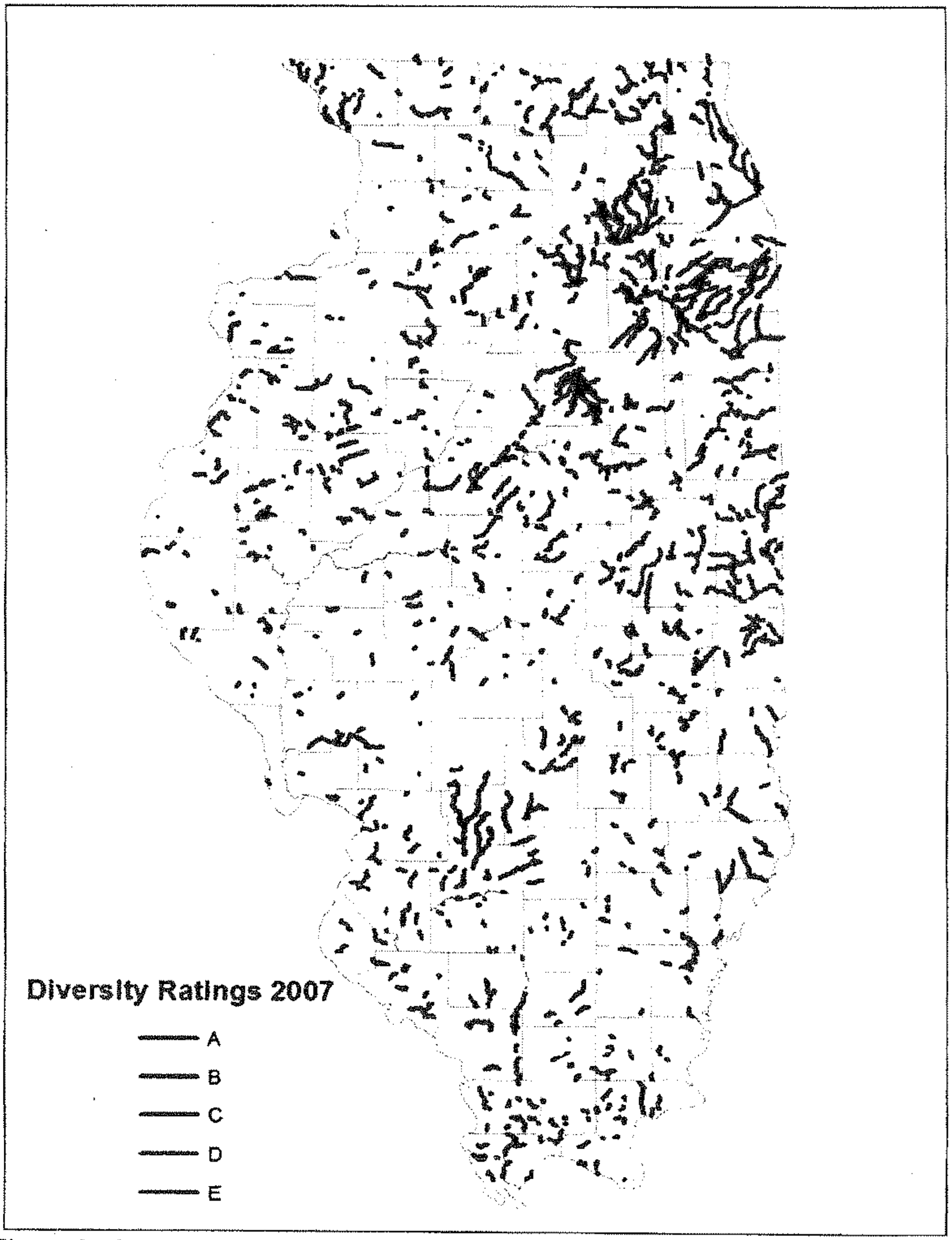

Figure 2. Geographic distribution of diversity ratings. Three percent of all valley segments for Illinois have a diversity rating. Access to the diversity data associated with individual streams is available at: http://dnr.state.il.us/biologicalstreamratings.

Integrity Ratings

Background

Biological integrity refers to a system's wholeness (Angermeier and Karr 1994) and the ability of a system to support organisms and processes comparable to natural habitat of the region (Hughes and Noss 1992). Indices or assessment measures like the fish and macroinvertebrate Indexes of Biotic Integrity (Smogor 2000, Tetra Tech, Inc. 2007) measure how closely a test community resembles a natural, least-disturbed, or intact community (see Stoddard *et al.* 2006 for a discussion of these terms). Intactness for fish and macroinvertebrates was determined from the indices of biotic integrity in comparison to least disturbed or reference sites. Intactness for mussels was determined in comparison to historical species richness expectations for a site. Three of the datasets that contribute to the integrity rating are multi-metric indices.

In December 2006, project stakeholders met and discussed the appropriateness of available datasets for inclusion in the integrity analysis. We considered data collected within the past decade (1997-2006) that were collected as part of IDNR, IEPA, or INHS monitoring programs. We limited data to these institutions to ensure that collection methods were standardized, repeatable, and will be continued in the future so that data will be available for revisions of these ratings.

Approach

The general approach for obtaining a diversity rating is a six step process.

Step 1. Select data for inclusion into the rating.

We considered only data that were collected within the past decade. However, if a single site had more than one sample from the past decade, we used the sample with the highest value for inclusion in the final rating calculation. We used this approach rather than taking the most recent sample or an average of the samples because the highest value represents a conservative estimate of the biological potential for the site and this approach accounts for variation that may occur with sampling. Additionally, we did not average the data from multiple samples since the average could represent a condition that had not been found at the site. The following data were used in the final integrity ratings.

Fish – Fish data from community samples taken as part of the cooperative Basin Survey Program and other department monitoring were provided by the IDNR. These data were reviewed by regional IDNR stream biologists to verify that the samples were representative community samples with adequate sampling efficiency. Fish Index of Biotic Integrity (IBI) scores from the compiled samples were used to calculate integrity ratings. A total of 744 sites with calculated Fish IBI scores were used in the final integrity score analysis (Table 7).

Table 7. The number of sites from each dataset used to calculate integrity scores.

Integrity Dataset	Number of Sites
Fish IBI	744
Macroinvertebrate IBI	452
Mussel Classification Index	134
Mussel Single Sample Intactness	329
Mussel Historical Intactness	366
Total	2025

Aquatic Macro***invertebrates*** – Benthic macroinvertebrate data were compiled from the IEPA in Springfield. These data are collected following protocols established for use in their Stream Condition Index (Tetra Tech, Inc. 2007), referred to as the Macroinvertebrate Index of Biotic Integrity (MIBI) in this project. A total of 452 sites with total MIBI scores were used for the final integrity score analysis (Table 7).

Mussels – Mussel data were obtained from the INHS mollusk collections database (http://www.inhs.uiuc.edu/cbd/collections/mollusk/molluskintro.html) and IDNR. Records associated with freshwater snails, fingernail clams, zebra mussels, and Asian clams were not included, as well as any records not located in streams. In order to query data that were representative of community samples, we restricted our data to a list of collectors' names obtained from Kevin Cummings, the INHS malacologist and mussel database manager. Three variables were used to determine integrity ratings for mussels: mussel community index (MCI), single sample intactness, and historical intactness.

Freshwater Mussel Classification Index (MCI)
Data were obtained from Bob Szafoni (IDNR) for sites where the MCI has been calculated (Szafoni 2002). The MCI is comprised of four metrics: species richness, abundance, presence of intolerant species, and recruitment (Szafoni 2002). Each of these metrics is scored and the scores are then summed to determine an index score. Although the MCI is comprised of multiple metrics like the fish IBI and MIBI, it differs from these because the response of these metrics to human impacts in watersheds has not been considered as part of the MCI development. Because reference conditions were not used to evaluate metrics, the resulting MCI scores do not represent how far a sampled mussel community is from a natural or reference condition but were designed to represent the characteristics of a healthy functioning community. Fundamentally this is different than the fish and macroinvertebrate IBIs, however we included the MCI in this project with the expectation that the index will be refined in the future and the availability of data will increase. A total of 134 sites were used for the final integrity score analysis (Table 7).

Intactness

One metric currently considered for inclusion into the MCI is community intactness, which is simply defined as the proportion of live species found at site to what is expected. Initial analysis suggested that the expected value increased with the number of samples available for a site. Therefore, we calculated both single sample and historical intactness values to account for different numbers of samples among sites.

Both intactness values were calculated for a site using the community sample from the past decade with the highest species richness of live mussel species divided by the total number of species including dead (dead and newly empty shells) and relict (old shells) specimens. For single sample intactness, the total number of species was from the single sample while for historical intactness it included all the species found at the site from all available samples. If both historical and single sample intactness were calculated for a site, then historical intactness was used in the final integrity ratings. A total of 366 historical intactness sites and 329 non-overlapping single sample intactness sites were used for the final integrity score analysis (695 total mussel sites, Table 7).

Step 2. Convert raw data to a class score.

One of the objectives for this project was to give equal weight to all communities of organisms found in streams if adequate and comparable sampling had occurred. To do this, we developed classes for each dataset used in the analysis in an attempt to interpret raw data from different sources and classify it similarly. Classes were independently developed for each dataset using each sample collection as an independent record rather than pooling samples from a single site. For example, if one site had multiple samples collected between 1997-2006, then each sample was treated as an independent record for the purpose of creating the class scores. Therefore, integrity and intactness expectations were based on the number of species you would expect to find in a single sampling event. Once the classes were established, only the sample that had the highest value from each site was used to calculate the final integrity rating.

Fish Index of Biotic Integrity — The fish Index of Biotic Integrity (IBI; Smogor 2000) scores were used as a component of the integrity rating. Because the IBI already had five integrity classes associated with the index (Smogor 2005), we maintained these classes with little modification. In the IBI, the integrity classes ranged from one (best) to five (worst). We reversed the numbering of the classes to give the sites with the highest IBI score a 5 instead of a 1.

Macroinvertebrate Index of Biotic Integrity (MIBI) — The MIBI (Tetra Tech, Inc. 2007) scores, based on seven metrics, were used as a component of the integrity rating. In the MIBI, final scores are placed into one of four classes, with one being the worst and four being the best. We maintained these four classes for this project.

Mussels

Mussel Classification Index (MCI)

Szafoni (2002) defined five classes for the MCI ranging from 0-4. We maintained classes 1 through 4 for the integrity ratings. Sites with a total score of 0 had no live mussels present and were not included in the final integrity rating calculations.

Intactness

We used the 90th percentile as the boundary for the highest class for datasets that were not developed with a reference site approach or did not have classes already developed for the index. Our rationale was that by raising the standard for the top class for intactness the 95th percentile, the highest class would be similarly restrictive as the datasets that did have reference site data available. We developed classes for historic and single sample intactness independently. For each, intactness classes consisted of the 1-10th percentile for class 1 and the 11-50th, 51-89th and 90th+ percentile for classes 2, 3, and 4 respectively. Similar to mussel species richness expectations, classes were assigned according to drainage and stream size (Tables 8 and 9).

Table 8. Mussel single sample intactness percentages that correspond to classes 1-4 for each drainage and stream size. Stream size is defined by link number, which is the number of first order streams based on the 1:100,000 National Hydrography Dataset (NHD) upstream of a given stream reach. Link codes refer to groupings of link numbers.

		Single Sample Intactness Percentage			
Stream Size	**Drainage**	**Class 1**	**Class 2**	**Class 3**	**Class 4**
Small					
(Link code 1)	Illinois	1-27	28-65	66-83	84+
	Mississippi	1-19	20-50	51-83	84+
	Ohio	1-20	21-42	43-54	55+
	Wabash	1-33	34-60	61-79	80+
Medium					
(Link code 2-3)	Illinois	1-26	27-71	72-90	91+
	Mississippi	1-35	36-71	71-88	89+
	Ohio	1-12	13-44	45-76	77+
	Wabash	1-20	21-50	51-82	83+
Large					
(Link code 4-6)	Illinois	1-21	22-50	51-83	84+
	Mississippi	1-32	33-64	65-77	78+
	Ohio	na	na	na	na
	Wabash	1-24	25-55	56-88	89+

Table 9. Mussel historical intactness percentages that correspond to classes 1-4 for each drainage and stream size. Stream size is defined by link number, which is the number of first order streams based on the 1:100,000 National Hydrography Dataset (NHD) upstream of a given stream reach. Link codes refer to groupings of link numbers.

Stream Size	Drainage	Historical Intactness Percentage Class 1	Class 2	Class 3	Class 4
Small					
(Link code 1)	Illinois	1-22	23-50	51-79	80+
	Mississippi	na	na	na	na
	Ohio	1-15	16-27	28-59	60+
	Wabash	1-17	18-50	51-71	72+
Medium					
(Link code 2-3)	Illinois	1-20	21-62	63-79	80+
	Mississippi	1-20	21-57	58-79	80+
	Ohio	1-14	15-31	32-53	54+
	Wabash	1-14	15-41	42-71	72+
Large					
(Link code 4-6)	Illinois	1-11	12-44	45-69	70+
	Mississippi	1-16	17-45	46-63	64+
	Ohio	na	na	na	na
	Wabash	1-13	14-40	41-62	63+

Step 3. Standardize classes into a proportional score (P score).

Proportional scores were used to standardize differing numbers of classes among variables. All metric/class scores range from "1" to a greater number with the greatest number always representing the highest class. In this step, we divided the assigned class score by the total number of classes available to obtain a proportional score (P score), which has a maximum of 1.

Step 4. Average the proportional scores within a given taxonomic group to obtain a single taxonomic score (T score).

Three datasets were potentially available for mussels: MCI score (Szafoni 2002), single sample intactness, and historical intactness. If both historical and single sample intactness were available for a site, then historical intactness was used in the final integrity ratings. When MCI and intactness scores were both available for mussels, then the average of the proportional scores was used to determine the taxonomic score (i.e., mussel taxonomic score). Creating a taxonomic score allowed us to include information derived from separate assessments into a combined signal for mussels. However, we averaged all available mussel information into a taxonomic score in order to give equal weight to fish, macroinvertebrates, and mussels in the final integrity rating.

Step 5. Average proportional and/or taxonomic score for multiple sites on a valley segment.

When multiple sites were associated with a particular valley segment for a dataset, the average of these proportional or taxonomic (for mussels) scores was used to calculate the final integrity score. An average from the different sites was used rather than considering the highest proportional score from the valley segment since conditions within the stream segment may vary and an average for the whole valley segment was a better representation than the signal from a single site.

Step 6. Determine the final integrity rating for a valley segment.

The final integrity score was calculated as:

Integrity Score = average (average fish IBI P scores + average MIBI P scores + average mussel T scores), where P score = proportional score and T score = taxonomic score

Examples of Integrity Ratings

We provide several examples to further illustrate the integrity rating process (Table 10). In the first example only the single dataset of macroinvertebrate IBI is associated with the valley segment. The MIBI score is 39.99 which equals a class 2 out of 4; therefore the proportional score is 0.5. Since there are no other datasets available for this valley segment the final integrity rating is also 0.5 (Integrity Rating C).

In the second example both the MIBI and fish IBI are available. The fish IBI score is 47 corresponding to class 4 and a proportional score of 0.8. The MIBI score is 65.39 corresponding to class 3 and a proportional score of 0.75. The average of the fish IBI and MIBI proportional scores is calculated to determine the final integrity score of 0.775 which equates to an integrity rating of B.

In the third example, the fish IBI, MIBI, and two mussel datasets are available. The fish IBI score is 55 which is a class 4 score with a proportional score of 0.8. The MIBI score is 78.23 with a class score of 4 and a proportional score of 1. The mussel classification index score is 16 with a class score of 4 and a proportional score of 1. The single sample intactness percentage is 29 which is a class 2 score and a proportional score of 0.5. The two mussel proportional scores are averaged for a mussel taxonomic score of 0.75. The final integrity score is then the average of the fish IBI proportional score, the MIBI proportional score, and the mussel taxonomic score. The final score equals 0.85 and is equivalent to an integrity rating of B.

The cut-offs for the final integrity letter ratings were determined by visually inspecting the distribution of the integrity scores (Figure 3). We also attempted to have a similar percentage of rated valley segments within each letter category to the previous BSC projects. A total of 1019 valley segments were assigned an integrity rating of A-E (Figure 4). This represents 2.7% of the total valley segments. The percentage of valley segments with the assignment of ratings A - E is 9, 31, 45, 10 and 5 respectively. While this procedure has been developed for assigning ratings using multiple datasets, approximately one half of the total valley segments that were assigned an integrity score used data from only one dataset (Table 11).

Table 10. Examples of calculating integrity scores.

	Example with single dataset	Example based on Fish and Macroinvertebrate IBIs	Example with average of mussel datasets
Valley Segment	38663	29766	44269
Fish IBI score		47	55
Fish IBI class score		4	4
Fish IBI proportional score		0.8 (4/5)	0.8 (4/5)
Macroinvertebrate IBI score	39.99	68.39	78.23
Macroinvertebrate IBI class score	2	3	4
Macroinvertebrate IBI proportional score	0.5 (2/4)	0.75 (3/4)	1 (4/4)
Mussel Classification Index score			16
Mussel Classification Index class score			4
Mussel Classification Index proportional score			1 (4/4)
Mussel single sample intactness percentage			29
Mussel single sample intactness class score			2 (2/4)
Mussel single sample intactness proportional score			0.5
Mussel historical intactness percentage			
Mussel historical intactness class score			
Mussel historical intactness proportional score			
Mussel taxonomic score			0.75
Integrity score	0.5	0.775	0.85
Integrity rating	C	B	B

Table 11. The number of datasets contributing to final integrity ratings.

Datasets	Total Valley Segments
1	515
2	306
3	104
4	80
5	12
Total	1019

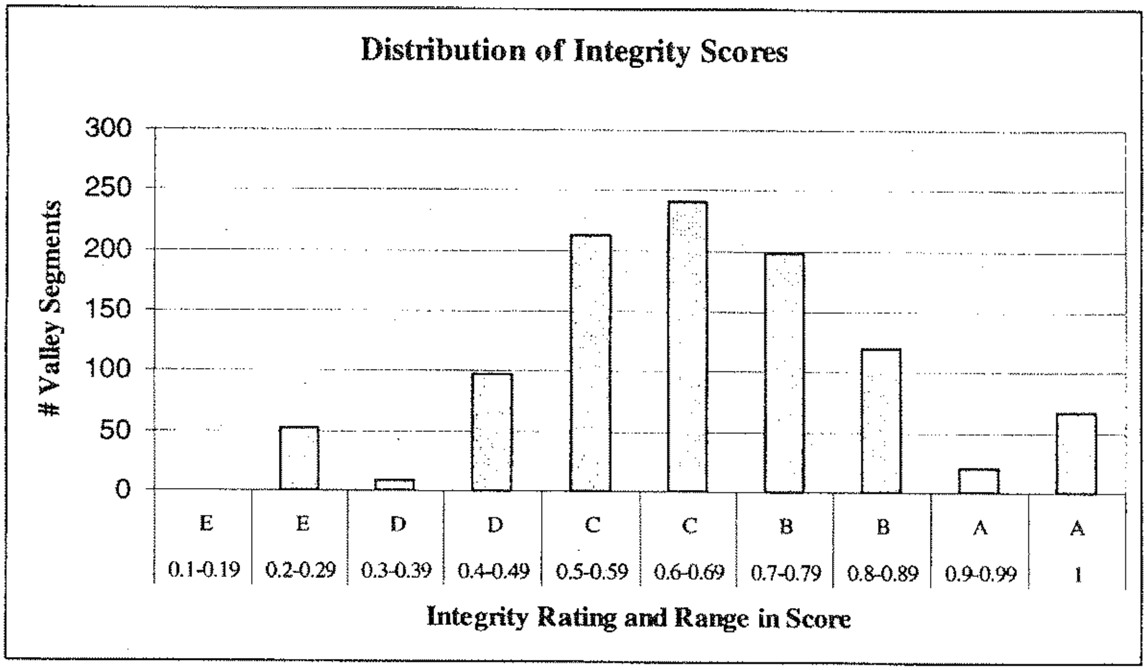

Figure 3. Distribution of integrity scores and corresponding letter rating. The percentage of valley segments with integrity ratings of A-E is 9, 31, 45, 10, and 5 respectively.

Map of Integrity Ratings

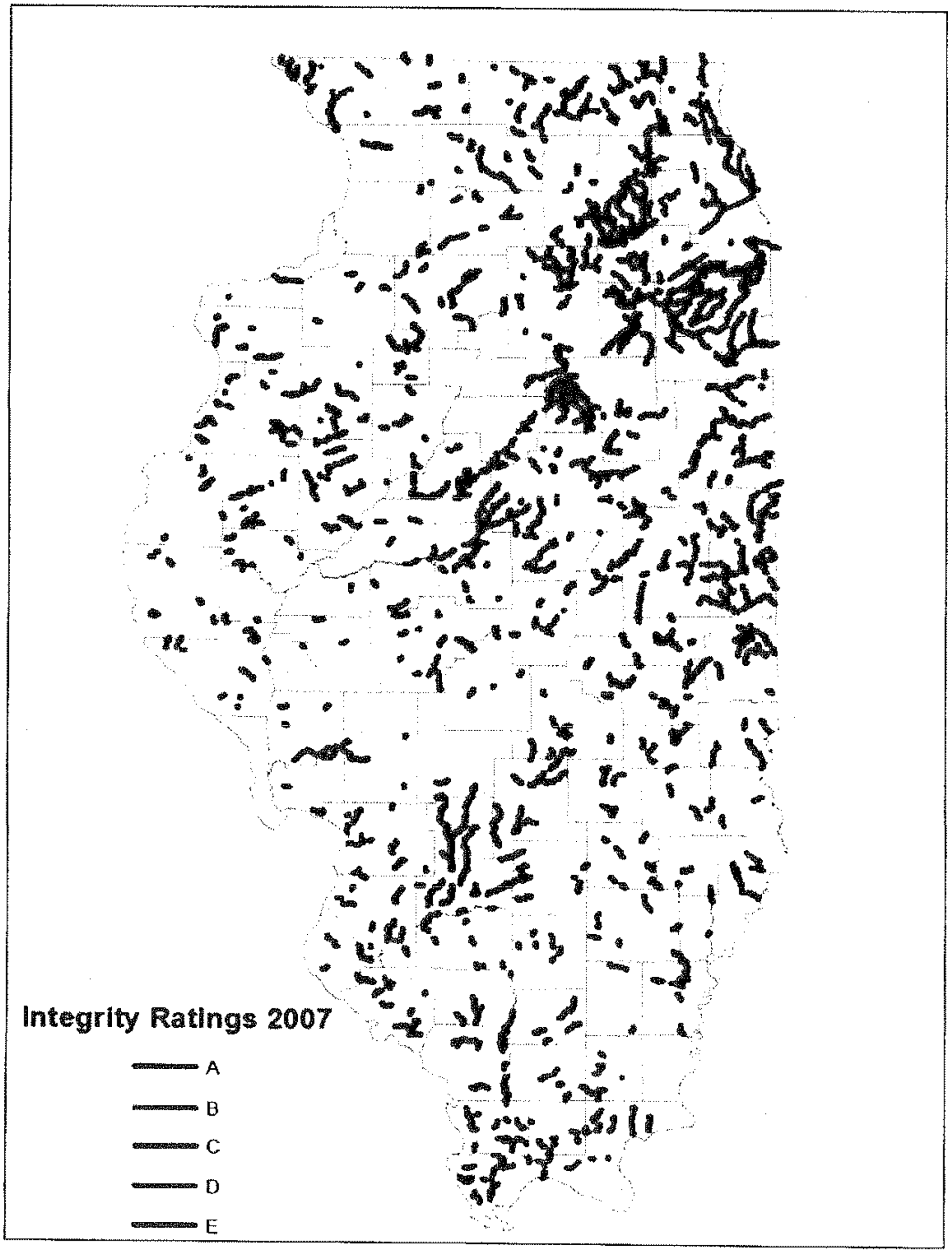

Figure 4. Geographic distribution of integrity ratings. Of the total 38,046 valley segments for the state, only 2.7% have an integrity rating. Access to the integrity data associated with individual streams is available at: http://dnr.state.il.us/biologicalstreamratings.

Biologically Significant Streams

Biologically Significant Streams (BSS) are defined as streams that have a high rating or score based on data from at least two taxonomic groups. This can be achieved by obtaining an A rating either for diversity or for integrity that is based on data from two or more taxonomic groups. A second way to achieve this status is for a stream segment to have class scores in the highest class for at least two different taxonomic groups when considering the combined data from the diversity and integrity ratings. While these criteria may seem more rigorous than the previous BSS assessment, we believe this is merited. By requiring BSS segments to have either an A rating or high class scores from separate assessments, we assured that only the highest rated reaches are given biologically significant status. By considering two taxonomic groups, we have more confidence in the BSS designation because at least two signals are indicating high biological significance within the stream.

A total of 1366 valley segments had data associated with them. Our primary criteria requiring a valley segment to contain the highest class score from two different taxonomic groups accounted for 84% of all BSS identifications. However, most valley segments (56%) that were identified as biologically significant also received an A rating for Diversity and/or Integrity (Table 12).

Table 12. The underlying qualifications for designation as a biologically significant stream (BSS). All BSS have at least two datasets from differing taxonomic groups associated with them. For streams with A ratings either for diversity or integrity, at least two datasets from different taxonomic groups had to contribute to the final rating. For streams that had the highest class/metric score, the two different taxonomic groups could be derived from a combination of both the diversity and integrity datasets.

Rationale	**Count**
2+ highest classes but no A ratings	54
Total with A rating	68
Total BSS valley segments	122

Breakdown 2+ highest class ratings	
Integrity A & 2+ highest classes	5
Diversity A & Integrity A & 2+ highest classes	11
Diversity A & 2+ highest classes	33
2+ highest classes but no A ratings	54
Total with 2+ highest classes	103

Breakdown A ratings	
Diversity A & Integrity A	1
Integrity A & 2+ highest classes	5
Diversity A	8
Integrity A	10
Diversity A & Integrity A & 2+ highest classes	11
Diversity A & 2+ highest classes	33
Total with A Rating	68

Stream segments identified as biologically significant are unique resources in the state and we believe that the biological communities present must be protected at the stream reach, as well as upstream of the reach. It is well documented in the scientific literature that the physical and chemical properties of water at a stream site reflect upstream influences (Omernick *et al.* 1981, Smart *et al.* 1981, Hunsaker and Levine 1995). However, we are unaware of any criteria that can definitively identify the upstream extent of influence on biota within each stream reach identified as biologically significant. Therefore, we used some simple, practical constraints for extrapolating from site-specific information to upstream stream segments to arrive at the segments identified as biologically significant. Stream reaches (i.e., arcs defined as confluence to confluence reaches) upstream of a valley segment that was identified as BSS were also identified as biologically significant if ALL of the following criteria applied:

1) The nearest downstream valley segment has sufficient biological information to warrant BSS status.

2) The stream reach is part of the BSS and not a tributary connecting to it.

3) The stream reach is not smaller than third order in size. Stream order is a relative measure of stream size; larger orders represent larger streams. Using third order as a size limit is consistent with the extent of range for the majority of fish, mussel, and macroinvertebrate information used, which predominately was collected from third-order streams and larger. Importantly, not all stream segments smaller than third order were denied BSS status outright. As per the first criterion, regardless of stream size, if sufficient biological information was available from the valley segment and the information indicates high integrity or diversity, the segment was identified for BSS status.

4) The stream reach is free-flowing, i.e., not obviously part of a lake, reservoir, or large river.

Map of Biologically Significant Streams

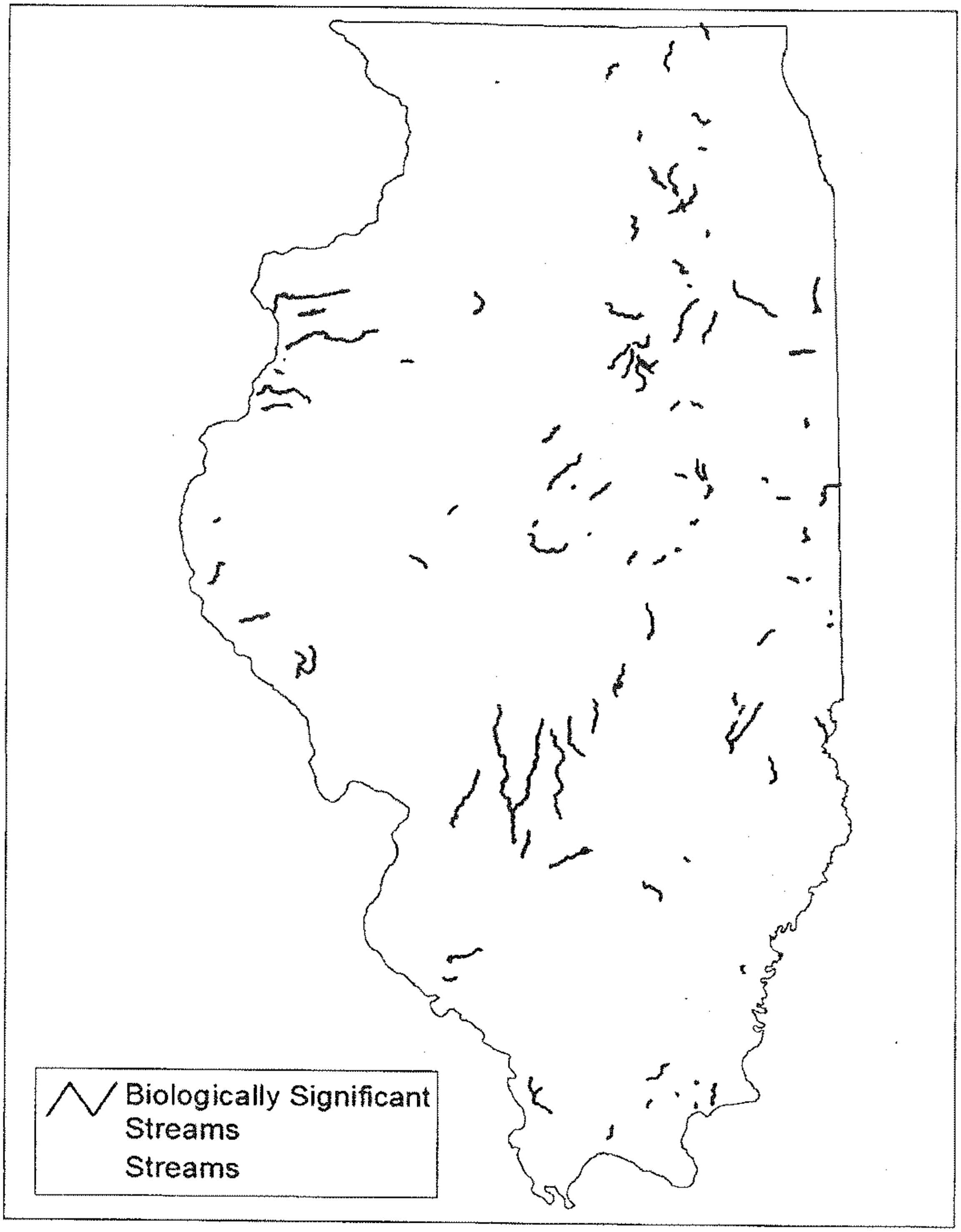

Figure 5. Geographic distribution of biologically significant streams. Access to the data associated with individual streams is available at: http://dnr.state.il.us/biologicalstreamratings.

Conclusions

The ratings proposed in this document incorporate aspects of both previous BSC and BSS processes. Since the publication of BSC and BSS, new initiatives have been implemented to collect biological information relevant to streams such as the Critical Trends Assessment Program, Mussel Classification Index, and the Benthic Macroinvertebrate Stream Condition Index (MIBI in this report). The fish IBI has also been revised and the list of threatened and endangered species has changed since the original publication of BSS. With the additions and changes to these data sources, it was pertinent to reassess the strengths and weaknesses of the previous stream ratings in the context of supporting implementation of Illinois' Wildlife Action Plan.

The Illinois Wildlife Action Plan identifies a broad array of species in greatest need of conservation, and therefore it was appropriate to consider multiple taxonomic groups in this project. In keeping with the Illinois Wildlife Action Plan's stream habitat goal that: "High–quality examples of all river and stream communities . . . are restored and managed within all natural divisions in which they occur", the current stream ratings and identification of biologically significant streams provide a new and updated tool to identify and target such areas. By combining multiple datasets from different taxonomic groups into a single rating, this project gives ratings that are a holistic representation of stream biological resources. Because we considered data in addition to fish, ratings were applied to an additional 483 valley segments that lacked fish data.

Data Issues

Other taxonomic groups were investigated but not used because of limited available data. For example, information on amphibians and reptiles in Illinois were obtained from the INHS amphibian and reptile collection. Of the listed amphibian and reptile species, the Dusky Salamander, is a species found in stream habitat (Phillips *et al.* 1999) and is considered an indicator species in small streams without fish (Southerland *et al.* 2004). While we included the Dusky Salamander in with the T&E species, we did not include other reptiles and amphibians because we lacked sufficient statewide information on the distribution of herpitiles inhabiting streams.

Plant information was also pursued because other species had been included previously in the Biologically Significant Illinois Streams (Page *et al.* 1992) publication. However, of the plant species that are still protected under the Illinois Endangered Species Protection Act, only the heart-leaved plantain (*Plantago cordata*) is considered an associate of stream habitat (Herkert and Ebinger 2002). Many of the species included in the original BSS were aquatic plants associated with pond habitats and therefore were not included in our analysis. We consulted State experts, including INHS personnel previously involved with BSS (Page *et al.* 1992), to determine if other potential botanical datasets were available. However, no additional plant species were included in our ratings since there have not been systematic statewide surveys of plants associated with stream habitat.

Updates and Revisions

One of the goals of the previous BSC initiatives was to update stream ratings on an annual basis and to publish the revised ratings every five years. However, the original BSC stream ratings were updated only once based on data that were collected through

1993. Similarly, the BSS project was based on data collected through 1991 and has not been updated since. Therefore, stream designations identified in these projects are based on data that is at least 14 years old. Given that these ratings are used by a diverse group of stakeholders, it is clear an updated version was required.

Several reasons may explain why previous stream ratings have changed through this project including: a new process evaluating diversity and integrity data, addition of data previously unavailable, revision to the fish IBI and T&E species list, and changes in stream condition. Because previous stream ratings may have changed for these reasons, comparisons of new ratings to previous ratings (from Hite and Bertrand 1989, Page *et al.* 1992, Bertrand *et al.* 1996) are not appropriate. For example, a stream reach rated as C in this report that was previously B should not be interpreted automatically as a degradation in stream quality. In addition to a revised process for assigning letter grades, biologically significant streams must now have data from two different taxonomic groups. Therefore, some streams previously identified as BSS did not receive the BSS designation in this effort because they lacked sufficient data given the change in criteria.

The ratings included in this report can assist in identifying streams that are in need of restoration or improved conservation. Given that less than 5% of the valley segments in the state have data associated with them, this project also indicates data gaps and can help prioritize future survey efforts. Current fish and macroinvertebrate indexes are only applicable to wadeable streams, thus we limited ratings to wadeable conditions. Development of assessment tools for headwaters and larger rivers would allow broader application of ratings in the future. Systematic surveys of mussels and crayfishes would support index refinement and broader inclusion of these taxa. As statewide surveys increase, the inclusion of other taxa such as herpitiles or aquatic macrophytes may be possible in future updates of the stream ratings.

The final product of diversity and integrity ratings with the identification of biologically significant streams indicates the data sources that contribute to each final rating and includes the proportional scores for these data. This information, available at http://dnr.state.il.us/biologicalstreamratings, will enable different stakeholders with varying goals to use the ratings and contributing data for their particular purposes. For example, if a stakeholder wanted to target their efforts at streams with high mussel species diversity they would be able to identify those streams according to the mussel species richness proportional score contributing to the final diversity score. Similarly, efforts focused at streams with a high fish IBI score could consider the fish IBI proportional score contributing to a final integrity score.

The major data collection programs (collaborative basin surveys, CTAP, Endangered Species Board updates) used in this project operate on a five year interval to assess streams statewide. Therefore, the IDNR intends to update ratings annually at http://dnr.state.il.us/biologicalstreamratings and publish new ratings, including designating biologically significant streams, after the completion of each round of basin surveys. A published revision of ratings should be available approximately every 5-6 years. With each published update, a new range of data from each of the sources will be selected to encompass the last ten years. For certain datasets such as the fish and macroinvertebrate IBIs, the values that correspond to the class scores will not have to be recalculated since they were already established. However, for other datasets such as the mussel species richness and intactness data, the number of species that correspond to the percentiles that were used to determine class scores will undoubtedly change with the collection of additional data. For these datasets, the values that represent the different class scores should be recalculated using the new data for each revision until these values can be more formally established. In addition, the cut-offs for the letter ratings are based on the distribution of the final scores. In the future these cut-offs could change as new data are analyzed. Therefore, the final scores that correspond to the letter ratings A-E should be reevaluated with any update.

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