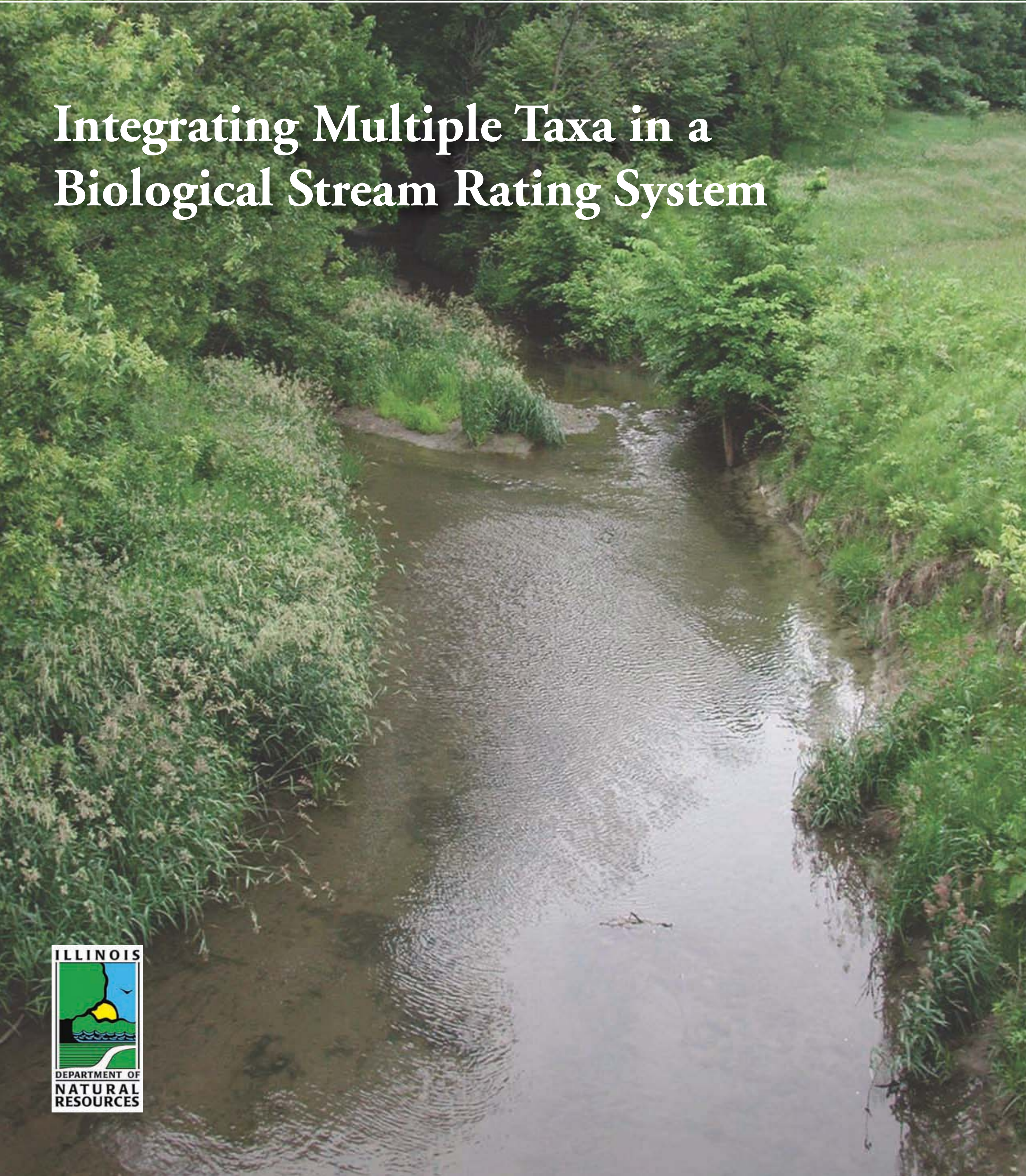
State of Illinois
Rod R. Blagojevich, Governor

Illinois Department of Natural Resources
Office of Resource Conservation

Integrating Multiple Taxa in a Biological Stream Rating System



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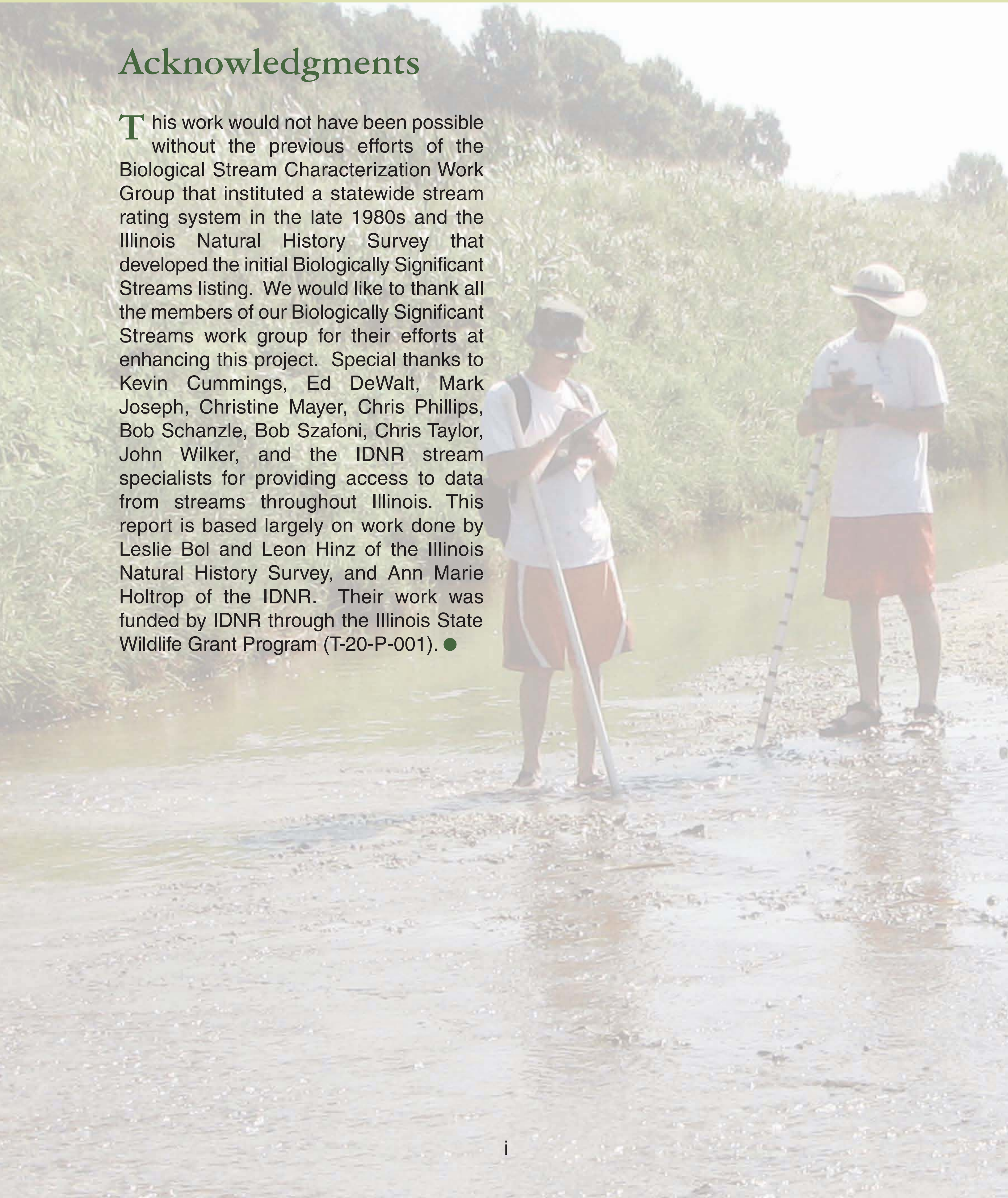

Preface

Updated stream ratings are provided in this report under authority of state law (see 515 ILCS 5-5 and 520 ILCS 5/2.1). This state law provides the Illinois Department of Natural Resources (IDNR) with ownership of the wildlife and aquatic resources residing within the borders of the State of Illinois. The IDNR is designated as the agency of state government charged with the regulation, protection, and preservation of those natural resources. Tools such as the stream ratings provided in this report are used by IDNR as the basis for field program implementation for resource protection. 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://www.dnr.state.il.us/orc/BioStrmRatings/. 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.●

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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 updated 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 (BSS). 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 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. 2008). 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.

Table 1. The number of sites from each dataset 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

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

Macroinvertebrate Taxa Richness

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 A 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).

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 75th 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 each class in the Macro-invertebrate Index of Biotic Integrity (Tetra Tech, Inc. 2007).

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)).

Bonus Points – The final diversity rating also integrates information about taxa that

Table 4. Class scores for mussel species richness values 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 percentille)	Class 3 (90th percentile +)
Small (Link code 1)				
	Illinois	<3	3 - 7	8+
	Mississippli	<2	2 - 5	6+
	Ohio	1	2	3+
	Wabash	<3	3 - 8	9+
Medium (Link code 2 - 3)				
	Illinois	<5	5 - 11	12+
	Mississippli	<5	5 - 10	11+
	Ohio	<2	2 - 3	4+
	Wabash	<5	2 - 10	11+
Large (Link code 4 - 6)				
	Illinois	<5	5 - 11	12+
	Mississippli	<7	5 - 11	12+
	Ohio	<2	2 - 5	6+
	Wabash	<6	6 - 13	14+
Mainstem (Link code 7)				
	Illinois	<9	9 - 10	11+
	Mississippli	<15	15 - 20	21+
	Ohio	<6	6 - 13	14+
	Wabash	<3	3 - 9	10+

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 were 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)

Aquatic 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 for a valley segment was 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.

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 5).

Table 5. Number of datasets contributing to final diversity ratings.

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

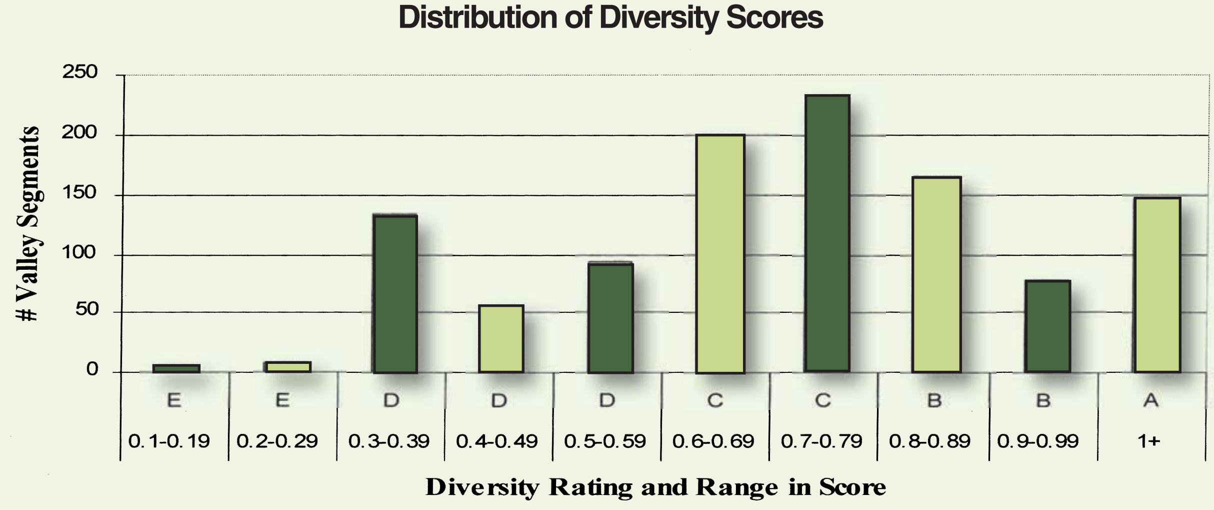

Figure 1. Distribution of diversity scores and corresponding letter rating. The percentage of valley segments with diversity ratings of A-E is 13, 22, 38, 25, and 1 respectively.

Examples of Diversity Ratings

To further illustrate the diversity process, we present several examples (Table 6). 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

Table 6. 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

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.

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, which represents a class score of 3 and a proportional score of 1. There is one S1S2 EPT species associated with the valley segment that is awarded 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 for calculating a 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 respectively. 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, which equals an A rating.

Map of Diversity Ratings

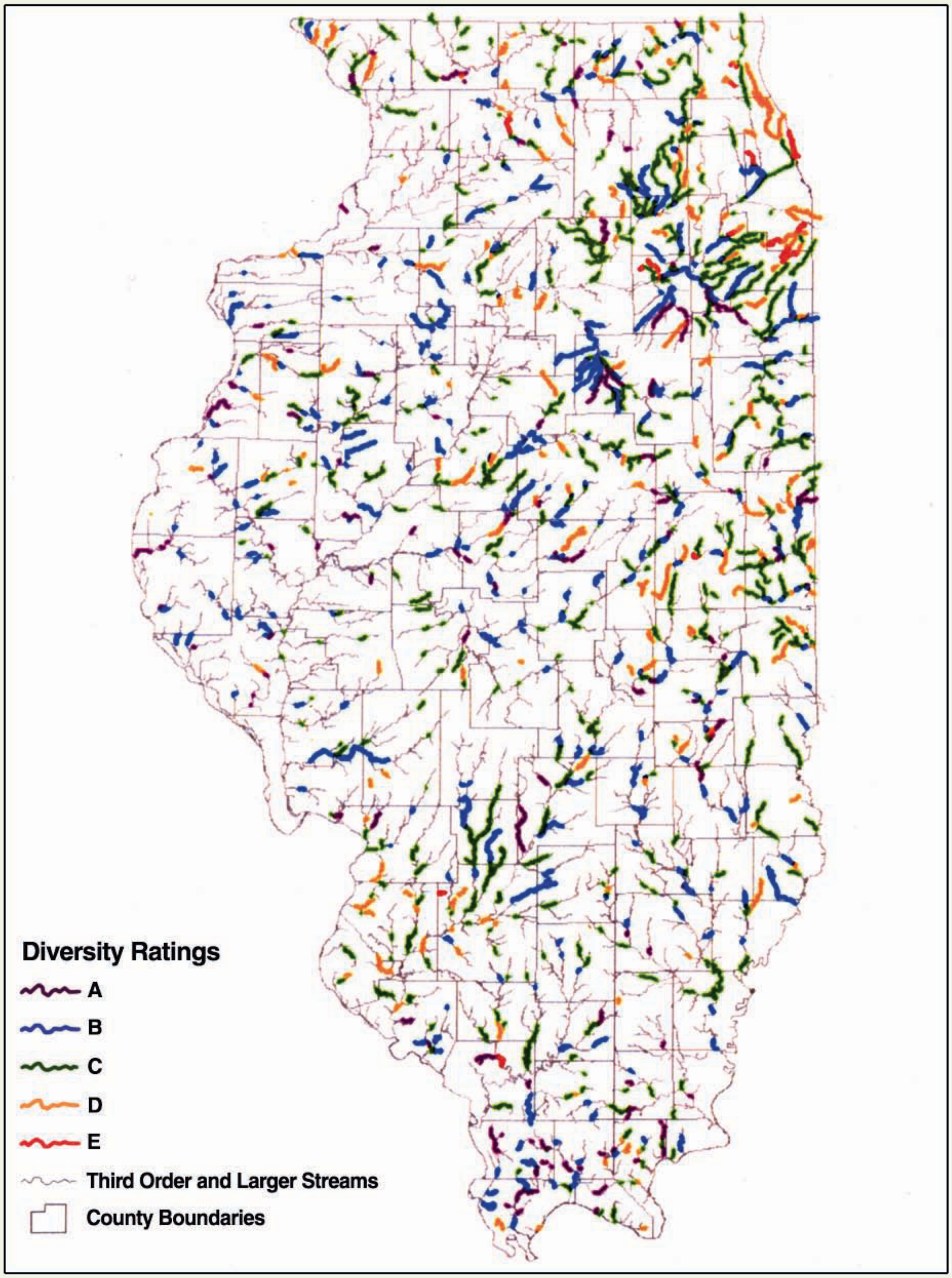

Figure 2. Geographic distribution of diversity ratings. Three percent of all valley segments for Illinois have a diversity rating. Access to the diversity data associated with individual streams is available at: http://www.dnr.state.il.us/orc/BioStrmRatings/.

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. 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 an integrity 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 because 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 Index of Biotic Integrity (IBI; Smogor 2000) 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 Macroinvertebrates – Benthic macroinvertebrate data were compiled from the IEPA in Springfield. These data were 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 metrics included in MCI 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. Rather, they were selected 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 90th 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).

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

Table 8. Class scores for mussel single sample intactness percentages 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.

		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	72 - 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. Class scores for mussel single sample intactness percentages 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.

		Historical Intactness Percentage			
Stream Size	Drainage	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+

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 for a valley segment 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

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 10).

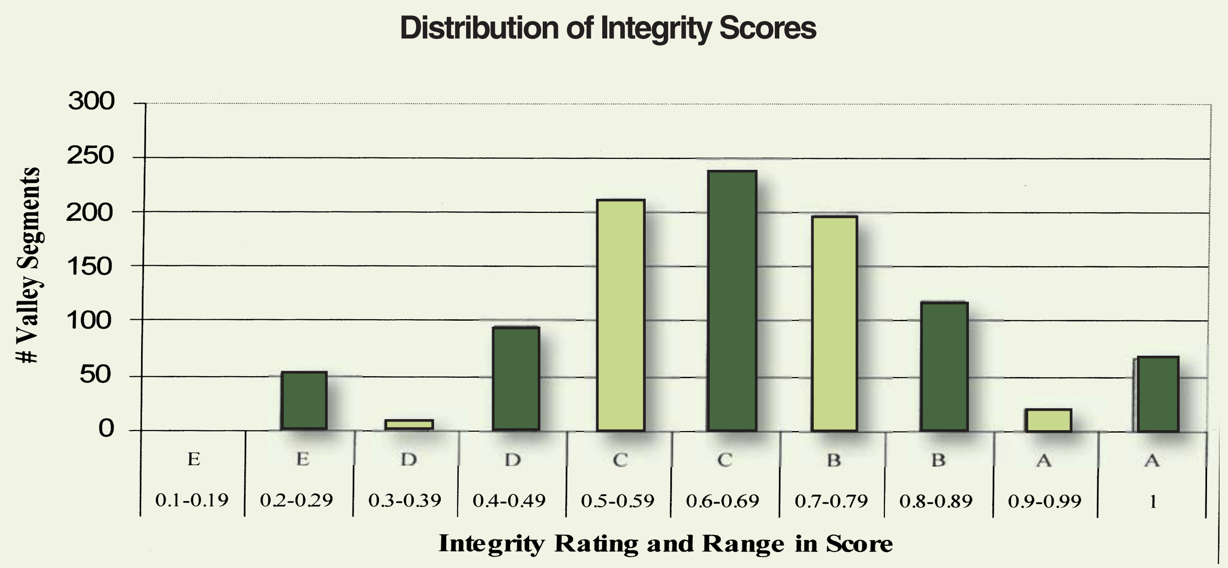

Figure 3. Distribution of integrity scores and corresponding letter ratings. The percentage of valley segments with integrity ratings of A-E is 9, 31, 45, 10, and 5 respectively.

Examples of Integrity Ratings

We provide several examples to further illustrate the integrity rating 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 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).

Table 10. 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

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

Table 11. Examples of calculating integrity scores.

	Example with single dataset	Example based on Fish and Macroinvertebrate IBIs	Example with t 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

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, which is equivalent to an integrity rating of B. ●

Map of Integrity Ratings

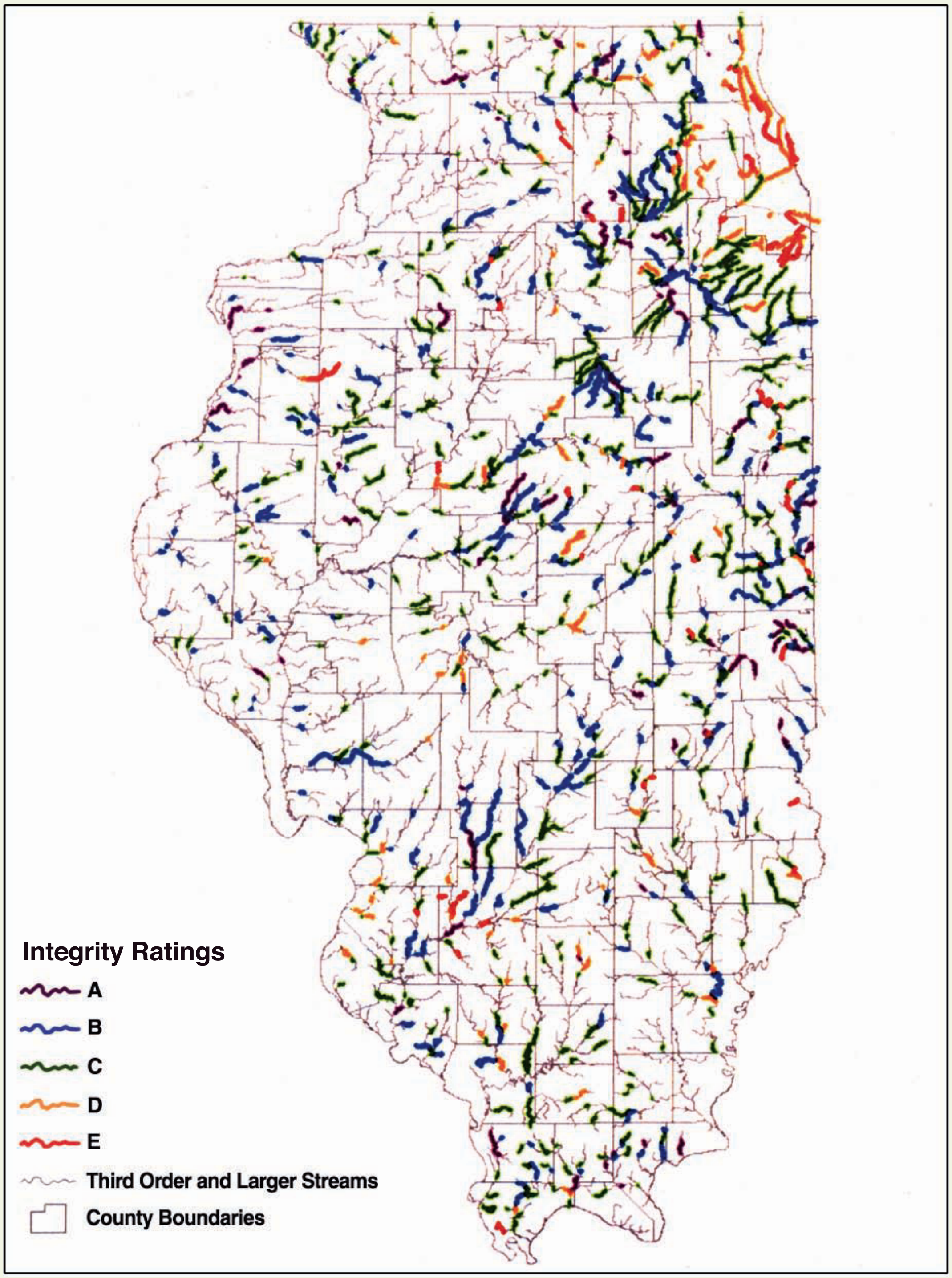

Figure 4. Geographic distribution of integrity ratings. Of the total 38,046 valley segments for the state, only 2.7% have an integrity rating. Access to the integrity data associated with individual streams is available at: http://www.dnr.state.il.us/orc/BioStrmRatings/.

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).

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 final 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

Table 12. The underlying qualifications for designation as a biologically significant stream (BSS). All BSS were evaluated based on information from at least two datasets from differing taxonomic groups. For streams rated A 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 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

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

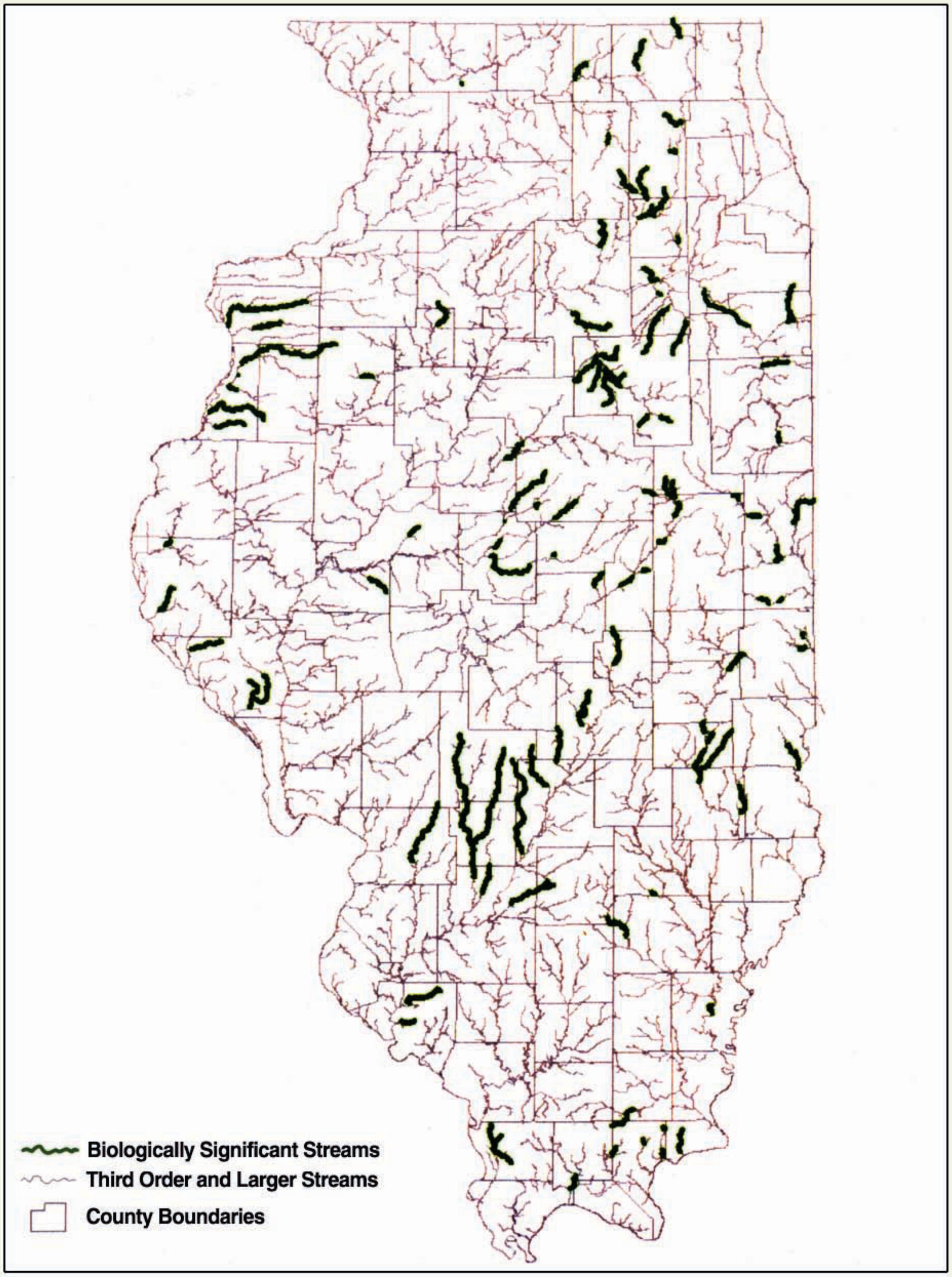

Figure 5. Geographic distribution of biologically significant streams. Access to the data associated with individual streams is available at: http://www.dnr.state.il.us/orc/BioStrmRatings/.

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 multiple species were 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 was clear that 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 and biologically significant streams, available at http://www.dnr.state.il.us/orc/BioStrmRatings/, indicates the data sources that contribute to each final rating and includes the proportional scores for these data. This information 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://www.dnr.state.il.us/orc/BioStrmRatings/ 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.

Literature Cited

Angermeier, P.L. and J.R. Karr. 1994. Biological integrity versus biological diversity as policy directives. BioScience 44:690-697.

Bertrand, W. A., R. L. Hite, and D. M. Day. 1996. Biological stream characterization (BSC): Biological assessment of Illinois stream quality through 1993. Illinois Environmental Protection Agency, Bureau of Water, Springfield, IL. IEPA/BOW/96-058.

Brenden, T.O., L. Wang, P.W. Seelbach, R.D. Clark, Jr., M.J. Wiley, and B.L. Sparks-Jackson. 2008. A spatially constrained cluster program for river valley segment delineation from GIS digital river networks. Environmental Modeling and Software 23: 638-649.

DeWalt, R. E., C. Favret, and D. W. Webb. 2005. Just how imperiled are aquatic insects? A case study of stoneflies (Plecoptera) in Illinois. Annals of the Entomological Society of America 98(6): 941-950.

Diamond, J.M. and V. B. Serveiss. 2001. Identifying sources of stress to native aquatic fauna using a watershed ecological risk assessment framework. Environmental Science and Technology 35:4711-4718.

Favret, C. and R. E. DeWalt. 2002. Comparing the Ephemeroptera and Plecoptera Specimen Databases at the Illinois Natural History Survey and Using Them to Document Changes in the Illinois Fauna. Annals of the Entomological Society of America 95(1): 35-40.

Fruend, J. G. and J. T. Petty. 2007. Response to fish and macroinvertebrate bioassessment indices to water chemistry in a minded Appalachian watershed. Environmental Management 39:707-720.

Herkert, J. R. and J. E. Ebinger. 2002. Endangered and Threatened Species of Illinois: Status and Distribution. Volume 1: Plants. Illinois Endangered Species Protection Board, Springfield, Illinois. 161 pp.

Hite, R. L., and W. A. Bertrand. 1989. Biological stream characterization (BSC): A biological assessment of Illinois stream quality. Special Report #13 of the Illinois State Water Plan Task Force. IEPA/AC/89-275.

Holtrop, A. M. and C. R. Dolan. 2003. Assessment of streams and watersheds in Illinois: Development of a stream classification system and fish sampling protocols. Aquatic Ecology Technical Report 03/15. 28 pp.

Hughes, R.M. and R. F. Noss. 1992. Biological diversity and biological integrity: current concerns for lakes and streams. Fisheries 17:11-19.

Hunsaker, C.T. and D.A. Levine. 1995. Hierarchical approaches to the study of water quality in rivers. BioScience 45:193-203.

Kilgour, B. W. and D. R. Barton. 1999. Associations between stream fish and benthos across environmental gradients in southern Ontario. Freshwater Biology 41:553-566.

Lammert, M. and J. D. Allan. 1999. Assessing biotic integrity of streams: Effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. Environmental Management 23:257-270.

Omernick, J. M., Abernathy, A. R., and L. M. Male. 1981. Stream nutrient levels and proximity of agricultural and forest land to streams: some relationships. Journal of Soul and Water Conservation 36:227-231.

Page, L. M., K. S. Cummings, C. A. Mayer, S. L. Post, and M. E. Retzer. 1992. Biologically Significant Illinois Streams: An Evaluation of the Streams of Illinois based on Aquatic Biodiversity. Center for Biodiversity Technical Report 1992(1). 485 pp.

Paller, M. H. 2001. Comparison of fish and macroinvertebrate bioassessments from South Carolina coastal plain streams. Aquatic Ecosystem Health and Management 4:175-186.

Phillips, C. A., R. A. Brandon, and E. O. Moll. 1999. Field Guide to Amphibians and Reptiles of Illinois. Illinois Natural History Survey Manual 8. 300 pp.

Seelbach, P. W., M. J. Wiley, J. C. Kotanchik, and M. E. Baker. 1997. A Landscape-based Ecological Classification System for River Valley Segments in Lower Michigan. Michigan Department of Natural Resources Fisheries Research Report No. 2036. 51 pp.

Shreve, R. L. 1967. Infinite topologically random channel networks. Journal of Geology 75: 178-186.

Smart, M. M., T. W. Barney, and J. R. Jones. 1981. Watershed impact on stream water quality: a technique for regional assessment. Journal of Soil and Water Conservation 36:297-300.

Smogor, R. 2000. Draft manual for calculating Index of Biotic Integrity scores for streams in Illinois. Prepared for: Illinois Environmental Protection Agency and Illinois Department of Natural Resources. 23 pp.

Smogor, R. 2005. Draft manual for Interpreting Illinois Fish-IBI Scores. Prepared for: Illinois Environmental Protection Agency. 26 pp.

Southerland, M. T., R. E. Jung, D. P. Baxter, E. C. Chellman, G. Mercurio and J. H. Volstad. 2004. Stream salamanders as indicators of stream quality in Maryland, USA. Applied Herpetology 2:23-46.

State of Illinois. 2005. The Illinois Comprehensive Wildlife Conservation Plan and Strategy – version 1. Prepared by the Illinois Department of Natural resources and approved by the U.S. Fish and Wildlife Service.

Stoddard, J.L., D.P. Larse, C.P. Hawkins, R.K. Johnson, R.H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Szafoni, R.E. 2002. Freshwater mussel classification index. In Illinois natural areas inventory - approved standards and guidelines. pp. 66-71.

Tetra Tech, Inc. 2007. Illinois benthic macroinvertebrate collection method comparison and stream condition index revision. Prepared for: Illinois Environmental Protection Agency. 11 pp.

United States Geological Survey. 2000. The National Hydrography Dataset: Concepts and Contents. Available at: http://nhd.usgs.gov/chapter1/chp1_data_users_guide.pdf

Appendix A. List of threatened and endangered species included in stream ratings.

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

Endangered

Heart-leaved Plantain	*Plantain cordata*

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