Watershed Science Institute
Watershed Condition Series
Technical Note 2

Index of Biotic Integrity (IBI)

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"Biotic integrity" is based on the premise that the status of living systems provides the most direct and effective measure of the "integrity of water" (Karr, 1997)

The Index of Biotic Integrity (IBI) is a well-known indexing procedure commonly used by academia, agencies, and groups to assess watershed condition. This index has been used in throughout the United States and many countries internationally, and has proven to be a reliable means of assessing the effect of human disturbance on streams and watersheds. The IBI is not a standard method within the NRCS. However, it is useful for agency staff to be familiar with its principles and functions since many state water quality agencies use it to measure stream health. Additionally, this technique has direct application in conducting resource assessments. This technical note provides an overview of the IBI, as well as examples of how the Wetland Science Institute and other groups have used the IBI to gauge the relative effectiveness of conservation practices.

Introduction

The Index of Biotic Integrity (IBI) was first developed by Dr. James Karr to help resource managers sample, evaluate, and describe the condition of small warm water streams in central Illinois and Indiana (Karr 1981).[1] The phrase "biological integrity" comes from the 1972 Clean Water Act, which established "restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters". "Integrity" implies an unimpaired condition or quality or state of being complete. "Biotic integrity" is based on the premise that the status of living organisms provides the most direct and effective measure of the "integrity of water." (Figure 1) As a result of the Clean Water Act, resource managers began to target water resource restoration funds based not only on chemical water quality standards but also on biological status. The Index of Biotic Integrity (IBI) provides managers with a technique for evaluating the biological condition of the water resource.

The IBI quickly became popular, and was used by many investigators to assess warm water streams throughout the United States. Karr and his colleagues explored the sampling protocol and effectiveness in several different regions and different types of streams. As the IBI became widely used, different versions were developed for different regions and ecosystems. The original version had 12 metrics that reflected fish species *richness* [2] and composition, number and abundance of species, *trophic* organization and function, reproductive behavior, fish abundance, and condition of individual fish. The metrics were scored and summed to arrive at an index ranging from 60 (best) to 12 (worst). Newer versions generally retained most of the original metrics but some have

[1] From Simon and Lyons 1995.

been modified to improve sensitivity to environmental degradation in a particular region or type of stream. The IBI has also been tailored to reflect differences in fish species in a region, and other types of ecosystems such as estuaries, impoundments, and natural lakes (Figure 1 a,b).

In 1993, Karr developed a Benthic-Index of Biotic Integrity (B-IBI) modeled after the fish IBI. The B-IBI included 13 metrics based on benthic macroinvertebrate data collected from rivers in the Tennessee Valley (Kerans and Karr 1994). The B-IBI has not been as widely tested or used as the fish IBI, but some agencies and universities include the B-IBI in stream health assessments (Figure 2 a,b).

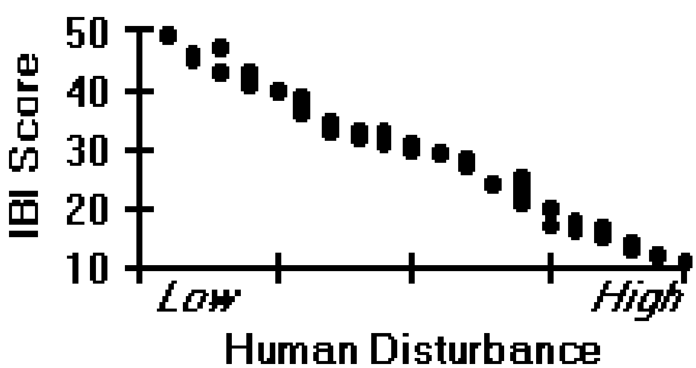

Figure 1a. Index of Biotic Integrity (IBI) use in wetlands. (IBI) scores for 40 wetlands in a USEPA wetland bioassessment study to classify wetlands (from bioassessment fact sheets prepared by Office of Watersheds and Wetlands at **http://www.epa.gov/owow/wetlands/wqual/bio_fact/index.html).**

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[2] Words in italics are defined in the glossary

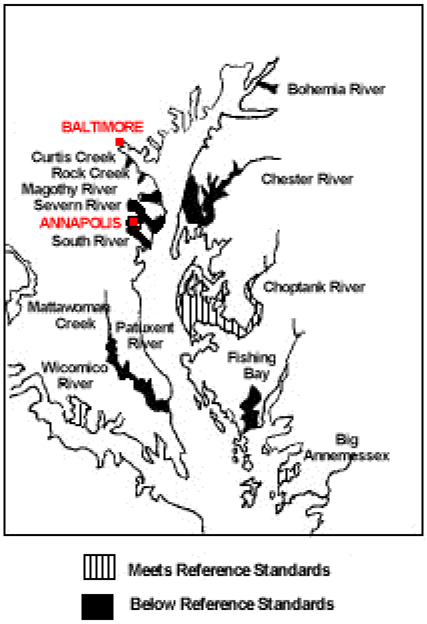


Figure 1b. Example of Index of Biotic Integrity (IBI) use in estuaries. Fish community indicators for the Chesapeake Bay tidal estuaries sampled between 1989 and 1997. IBI scores were averaged to get an overall rating for each tributary. (From Maryland Department of the Environment report on IBI use in estuaries, http://www.mde.state.md.us/).

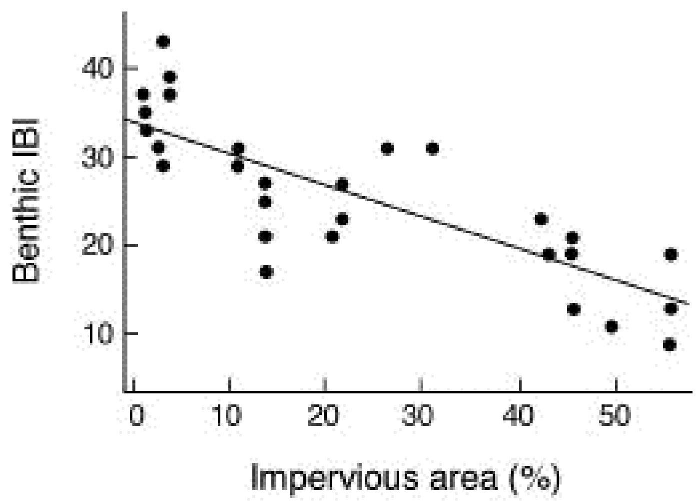


Figure 2a. Example of Benthic-Index of Biotic Integrity (B-IBI). B-IBI plotted against the percentage of impervious surface for urban, suburban, and rural streams in the Puget Sounds lowlands. The B-IBI decreases with increasing impervious area. (From Karr and Chu, 1997).

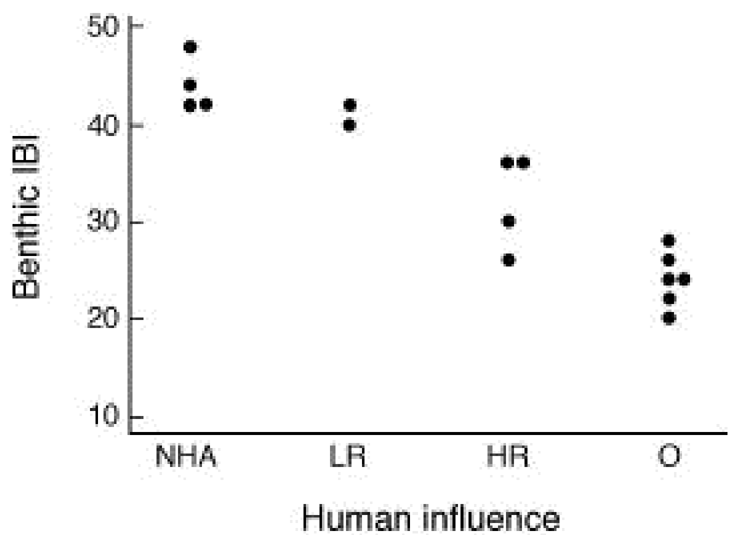
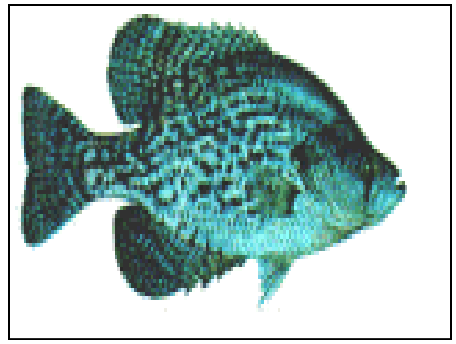


Figure 2b. Example of Benthic-Index of Biotic Integrity (B-IBI) use. B-IBI for stream sites in Grand Teton National Park, Wyoming. Sites were placed into four categories based on human influence: little to no human activity (NHA), light recreational use (LR), heavy recreational use (HR), and other (O). B-IBI showed no significant difference between sites with little recreational use, but B-IBIs were significantly lower for sites used heavily for recreation, and still lower for other uses: urban, grazing, agriculture, and wastewater discharge. (From Karr and Chu, 1997).

Living systems, such as fish used in the IBI, are useful in measuring degradation for many reasons:

- ✓ Fish are sensitive to a wide array of stresses.
- ✓ Fish integrate adverse effects of activities in the watershed.
- ✓ Fish are long-lived; their populations show effects of reproductive failure and mortality in many age groups and therefore provide a long-term record of environmental *stressors*.

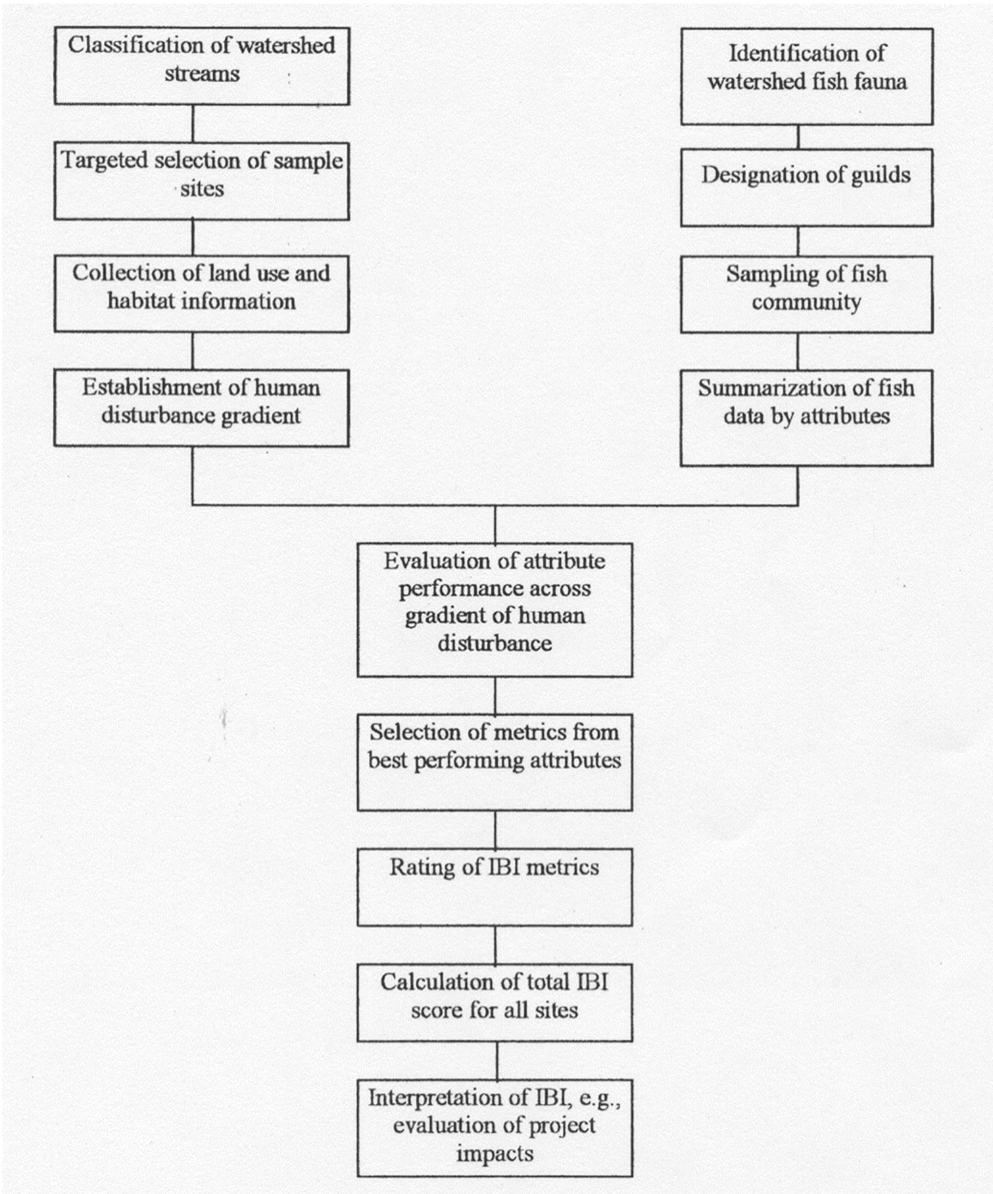


Determining an IBI score

A sequence of activities[3] in developing an IBI is provided in Figure 4. Project objectives are established in conjunction with a reconnaissance of the stream and its watershed. Areas are selected which reflect a range of conditions and site-specific impacts existing in the watershed. A statistical framework is generally the best approach

[3] See also www.esb.enr.state.nc.us/bavwww/IBI%20Methods%202.pdf

Figure 3. Sequence of activities involved in Index of Biotic Integrity (IBI) development.[4]



[4] From Teels and Danielson (2001) and Karr et al. (1986).

since human bias in site selection is reduced, however, this is often difficult due to limited budgets. Once sites are selected and goals of the study established, fish collection is initiated.

A 600-foot section of stream is generally sampled at each site.[5] A 30-foot wide stream requires a four-person team to adequately sample the stream. The team samples in an upstream direction, using a seine or electrofisher to sweep the stream corridor.

Figure 4. Fish samples are collected by means of seines or backpack electrofishers. A state permit is required for collection.

[5] Techniques for fish sampling vary. For example some studies use a 300-ft. stream length for sampling. Others may use species area curves to find best stream length to sample. For detailed information on sampling techniques and development and analysis of an IBI, see USDA-NRCS National Biology Handbook.

Fish are collected using electrofisher backpacks or seines. A state permit may be required to collect fish samples (Figure 5). Both left and right banks of the stream are sampled, taking care to include all stream habitats, such as riffles, pools, runs, snags, undercuts, and deadfalls (Figure 6). Stunned or seined fish are netted and placed in buckets until the end of sampling. At the end of the 600-foot section, the team pauses and allows the water to clear. The team then returns downstream to the starting point repeating the sampling procedure along the way. Once back at the starting point, all

Figure 5. Pools and areas under overhanging vegetation are some of the stream habitats sampled during fish collection.

fish are identified to species level, counted and measured. Sores and fish anomalies are also noted. In general, fish species identification requires a trained biologist or person familiar with fish assemblages in the area. Data are recorded and fish that can not be identified are preserved and returned to a laboratory for analysis. Fish are returned to the stream after completion of sampling and data recording. IBI scores are determined in the office using 10 to 12 metrics tailored for the area. An example of the metrics and a brief description are presented in Table 1.

Table 1. Example of metrics used to construct an Index of Biotic Integrity (IBI).[5]

Metric	Description
Number of fish species and individuals	The total number of species and individuals supported by the stream will decrease with environmental degradation.
Number of darters	Darters are sensitive to environmental degradation. Darter habitats may be degraded as the result of siltation, channelization, etc.
Number of species of sunfish	These species are particularly sensitive to silting in of pools and loss of in-stream cover.
Number of species of suckers	Suckers are intolerant of chemical and habitat degradation and because they are long lived provide a multiyear perspective.
Number of intolerant species	Intolerant species are most affected by stream degradation and therefore would disappear by the time a stream is rated as 'fair'.
Percentage of tolerant species	Tolerant species are present in moderate number but become dominant as stream degrades.
Percentages of omnivores (plant eaters), insectivores (insect eaters), and piscivores (fish eaters).	These are the trophic groups. The trophic groups describe what the fish species eats and where it is in the food web. Deviations from what is expected are noted. For example, the cause of a greater number of omnivores than insectivores is nutrient enrichment.
Percentage of diseased fish	Skeletal anomalies, fin damage, disease, and tumors increase with stream degradation.
Percentage of species with multiple age groups	Determines reproductive success of the fish population.

[5] From NCDHNR.1997. Example metrics for piedmont streams. Metrics are tailored to a particular region and are generally available through state departments of water quality.

The values of Index of Biotic Integrity (IBI) metrics are assigned a score- for example, 1, 3, or 5. These metric scores are added to arrive at a total IBI score. Ratings (very poor to excellent) which correspond to the IBI scores are developed. For example, some regions may rate an IBI score of 54-60 as excellent, whereas other regions might rate 49-54 as excellent. In general, an expert group determines the scorings and ratings and validates appropriateness for the region. Once scores and ratings are calculated for the sites, sites can be compared. Cause and effect relationships can be explored (Table 2). It is at this point that 'red flags' (such as very high or very low IBI scores) go up and specific sites may be targeted for further action. Some groups may wish to continue monitoring after site impacts are assessed and restoration has begun.

Table 2. Example of how the Index of Biotic Integrity (IBI) scores are used to evaluate site-specific impacts at four streams in the Lower Quachita Mountains Ecoregion, Arkansas (Adapted from Hlass, Fisher, and Turton, (1998)).

Stream	**Average IBI Score for Stream Reach**	**IBI Score for Site**	**Site Impact**
Caney	33	33	no site-specific impacts detected
Brushy	33	22	adjacent livestock pasture
Harris	29	26	cattle watering hole, adjacent clear cut area
Moore	24	18	pipe crossing with bare slopes, gullying

Exploring the value of Index of Biotic Integrity (IBI) to NRCS

Key to successful restoration, mitigation, and conservation efforts is using an objective method to assess conservation effects. The IBI is a recognized tool for doing so, and its use also allows managers to set realistic targets and evaluate the effectiveness of conservation practices. Two case studies are presented to demonstrate in-field, applied use of the IBI. In the first case study, the IBI was used to examine the effectiveness of wetland mitigation and restoration. The second case study shows how the IBI was used gauge the success of conservation practices.

<u>Case Study 1.</u>
Using an Index of Biotic Integrity (IBI) to assess the effects of mitigation on a wetland-stream ecosystem (Adapted from Teets et al. (1998).

This case study is a summary of a project conducted by Dr. Billy Teels, Director of NRCS Wetland Science Institute. Dr. Teels modified the IBI for use in a wetland-stream complex. The study area is a 20-acre artificial wetland created to mitigate the loss of a 21-acre beaver-influenced wetland-stream complex destroyed by the construction of a PL-566 impoundment in the Occoquan watershed, about 2 miles north of Warrenton, Virginia. The IBI was used to assess and monitor the condition and diversity of the fish assemblage in the project area before and after dam construction. The project was begun in 1993 and continued until 2000. Baseline fish assemblage data waere also available from an interagency study begun by NRCS in 1974.

Pre- and post-site condition of the mitigation area

The study area consisted of a small first-order stream with a complex of beaver ponds and adjacent saturated wetlands. The area was connected by a network of streams supplied by perennial flow from Cedar Run. These components formed a 20-acre wetland complex along Cedar Run. The mitigation area consisted of six back-to-back

Figure 7. The study area is a 20-acre artificial wetland created to mitigate the loss of a 21-acre beaver-influenced wetland-stream complex destroyed by the construction of a PL-566 impoundment in the Occoquan Watershed, about 2 miles north of Warrenton, Virginia. The artificial wetland consisted of six back-to-back cells constructed along Cedar Run flood plain. Each cell had three habitats: open water, semi-permanently inundated wetlands, and terrestrial islands.

cells upstream of the Cedar Run impoundment (Figure 7). The entire complex was inundated by construction of a dam in 1992. Six separate shallow-water pools were created along the Cedar Run flood plain. Each cell was designed to have three habitats: open water, semi-permanently inundated wetlands, and terrestrial islands. Construction resulted in conditions where the wetland cells were less well vegetated than the original complex. Construction also resulted in loss about 0.2 miles of flowing water.

Site selection and sampling of the mitigation area

This study was conducted to comply with a condition of the US Army Corps of Engineers Section 404 permit that required monitoring and evaluation of the mitigation area over a 3- to 5- year period. The IBI was tailored for the Occoquan watershed and used to evaluate biological condition of the wetland-stream complex before and after mitigation, and used to assess the efficacy of mitigation in simulating the original biological condition.

One hundred fifty-seven stream reaches were sampled representing three sizes of drainage areas in the Occoquan River and neighboring watersheds. Drainage area size classes were <4000 acres, 4000-8000 acres, and >8000 acres. This approach was taken to account for fish population variation due to size of drainage area; e.g., larger drainage areas are expected to have a greater number of fish species. Specific stream reaches (sites) were targeted within the three size classes to represent ranges in impairment due to human disturbance. Impaired and unimpaired sites were selected based on a drainage area's proportion of intensive agriculture, habitat impairment within the stream reach, isolation of fish due to movement barriers, and proportion subject to influences of urban runoff. These proportions were estimated using aerial photography, soil survey maps, environmental impact statements, US Environmental Protection Agency reports, and a visual, field-based reconnaissance of the watershed.

Conclusions

The study revealed an unexpected result, mitigation resulted in a lower biotic index than existed previously in the wetland-stream complex. The Index of Biotic Integrity (IBI) scores at the mitigation area reduced by half during the year following construction and have remained low ever since. Isolation resulting from barriers may have led to the fair IBI pre-mitigation scores. Adverse impacts may have been minimized or avoided by using the IBI to project the effects of the planned project and to make necessary design adjustments. Also, the IBI could have been used to identify degraded stream systems as better candidates for mitigation or restoration.

Results of this study show that the IBI could be used by NRCS to

- **Establish baseline conditions for site evaluation**
- **Minimize or avoid future adverse project impacts**
- **Help form alternatives for mitigation**
- **Locate degraded stream systems as candidates for restoration**

Case Study 2

Spatial and temporal variability of the index of biotic integrity in three midwestern streams (Adapted from Karr, Yant, and Fisher (1987)).

Introduction

The study was undertaken to study the IBI's sensitivity to changes in water quality. This study addressed the following questions:

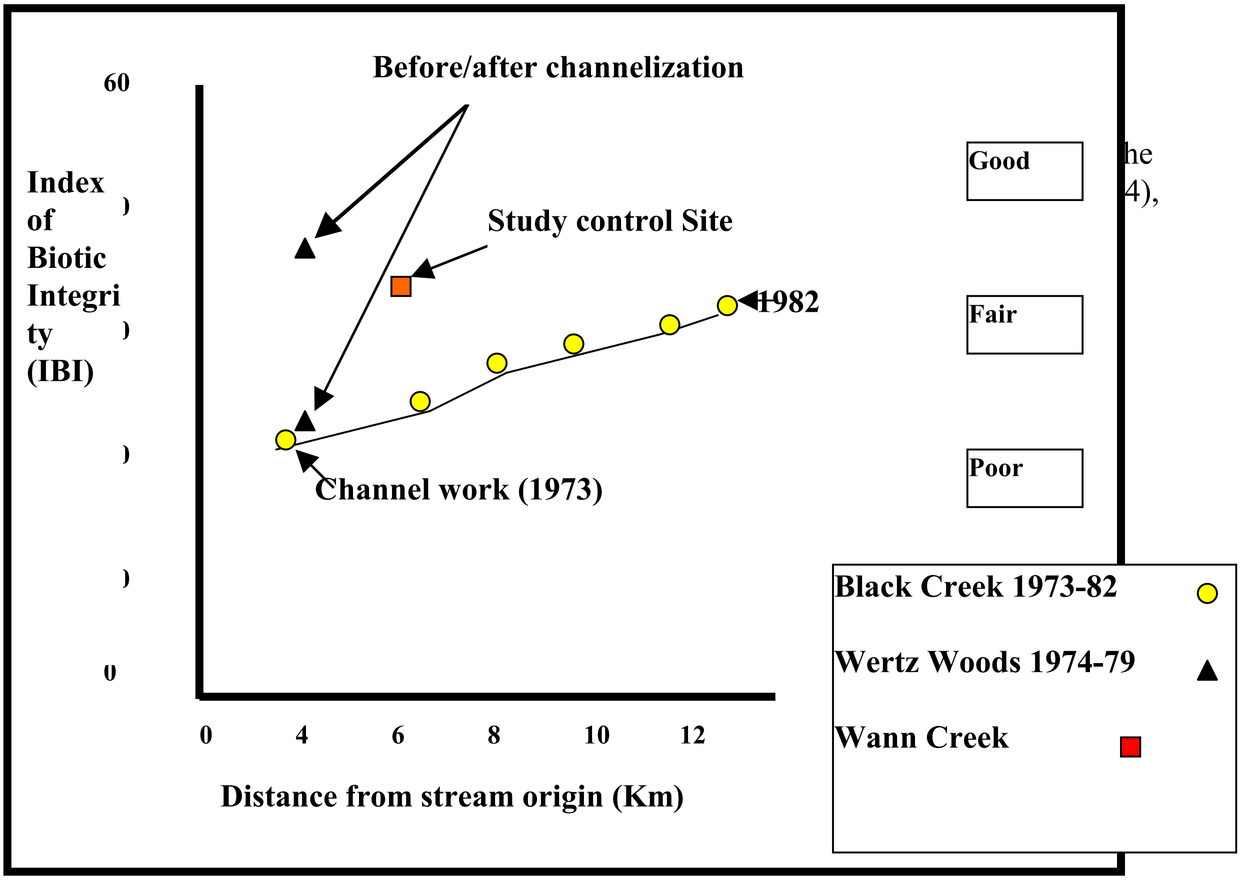
- Do site rankings by IBI reflect site quality assessments?
- Is the IBI sensitive to the impact of known habitat and water quality disturbances, and is recovery from these disturbances detectable?

The watersheds

Three watersheds with long-term fish community data were used in this study: Jordan Creek and Big Ditch near Champain-Urbana in east-central Illinois, and Black Creek in northeast Indiana. These watersheds were sampled for fish communities at various locations to reflect site characteristic differences. The watersheds were characterized as follows:

- Jordan Creek- 1) an upstream channelized reach with no riparian vegetation, 2) a channelized reach with 25 to 35-foot. strip of riparian vegetation, 3) an unchannelized reach bordered by well-vegetated pasture, and 4) a high gradient, unchannelized reach bordered by a 35 to 1300-foot wide strip of hardwood forest.
- Big Ditch- channelized throughout its length, no riparian vegetation, and receives municipal effluent from Rantoul, Illinois.
- Black Creek- channelized stream with non-point source pollution in the form of sediment, nutrients and toxic chemicals

IBI scores were determined from fish community metrics for the sites and compared to site habitat characteristics (Figure 8).



Before/after channelization
60
Index of Biotic Integrity (IBI)
Study control Site
1982
Good
Fair
Poor
Channel work (1973)
0
0
4
6
8
10
12
Distance from stream origin (Km)
Black Creek 1973-82
Wertz Woods 1974-79
Wann Creek

Key Findings

Relationship between IBI and habitat changes and recovery from disturbance (channelization)

- IBI scores were in agreement with the major habitat changes along the stream channels.
- The high-gradient, unchannelized stream reach with a hardwood border had the highest IBI values, whereas the channelized reach with no riparian vegetation had the lowest.
- Municipal effluent introduced above a sampling site in Big Ditch resulted in a sharp decline in the downstream IBI score.
- Recently channelized sections of Big Ditch has corresponding lower IBI scores compared to stream sections channelized in the 1940's.
- Channelized sections of Black Creek had low IBI scores compared to unchannelized sections of the creek. IBI scores improved with time in channelized sections of Black Creek reflecting better habitat quality, sinuous channel, pools and riffles, and trees shading the channel.

Another part of the Black Creek study was designed to implement plans for controlling erosion and to evaluate the effectiveness of traditional conservation practices in improving water quality. Conservation plans developed for farms throughout the Black Creek watershed included crop rotation, minimum tillage, contour planting, and channel stabilization. Changes in nutrient and sediment loads and changes in biotic integrity determined improvement in water quality. One reach of Black Creek watershed, Wertz Woods, showed slight improvement in water quality, but most of the watershed showed little improvement in biotic integrity from 1973 to 1982. Results from this part of the study warrant careful evaluation of treatment programs to control non-point source pollution.

Summary

The Index of Biotic Integrity (IBI) was first developed by Dr. James Karr to help resource managers sample, evaluate, and describe the condition of small warm water streams in central Illinois and Indiana (Karr 1981). The IBI quickly became popular, and was used by many investigators to assess warm water streams throughout the United States and internationally. Newer versions of the IBI have been modified to improve sensitivity to environmental degradation in a particular region or other types of ecosystems such as estuaries, impoundments, and natural lakes. The IBI is not a standard method within the NRCS. However, this technique has direct application in conducting resource assessments.[6] Resource managers can use the IBI as a tool to evaluate site-specific impacts, set realistic targets, and evaluate the effectiveness of restoration efforts and best management practices.

[6] See Teels, B.M. and T. Danielson.2001.

Glossary

Benthic macroinvertebrates. Small stream-inhabiting creatures that lack backbones, are small enough to be seen with the naked eye (larger than 0.05mm) and spend at least part of their life cycle in or on stream bottoms.

Biomonitoring. Evaluation of the condition of a waterbody, using biological surveys and other direct measures of the resident biota in surface waters.

Indicators. Anything measurement, directly measured or inferred, used to point out changes or status of something such as water quality.

Indices (plural of index). A numerical score usually derived from a series of indicators used to rate quality. A higher index score, such as in the evaluation of water quality, generally denotes higher quality.

Richness. The total number of different taxa of aquatic organisms such as fish or benthic macroinvertebrates in a sample, generally increases with increasing water quality.

taxa richness + total abundance

Taxa. A group of organisms such as a group of macroinvertebrates, which is used to represent the diversity within a sample. Taxa are used as a key metric in some biotic condition indices, for example, the Index of Biotic Integrity

Trophic (group). A stratum in the hierarchy of the food web

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